Efficiency Measurement of Dairy Farmers under Integrated Cropping Systems in Pakistan

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For my Family

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List of Abbreviations

CD	Cobb Douglas functional form
CRS	Constant Return to Scale
DEA	Data Envelopment Analysis
FAO	Food and Agriculture Organization
GDP	Gross Dometic Product
IFAD	International Fund for Agricultural Development
IFCN	International Farm Comparison Network
ITC	International Trade Centre
LDDDP	Livestock and Dairy Development Department (Punjab, Pakistan)
MRT	Marginal Rate of Transformation
RST	Returns to Scale
SD	Standard Deviation
SE	Standard Error
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency

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Chapter 1

An overview of agriculture sector in Pakistan

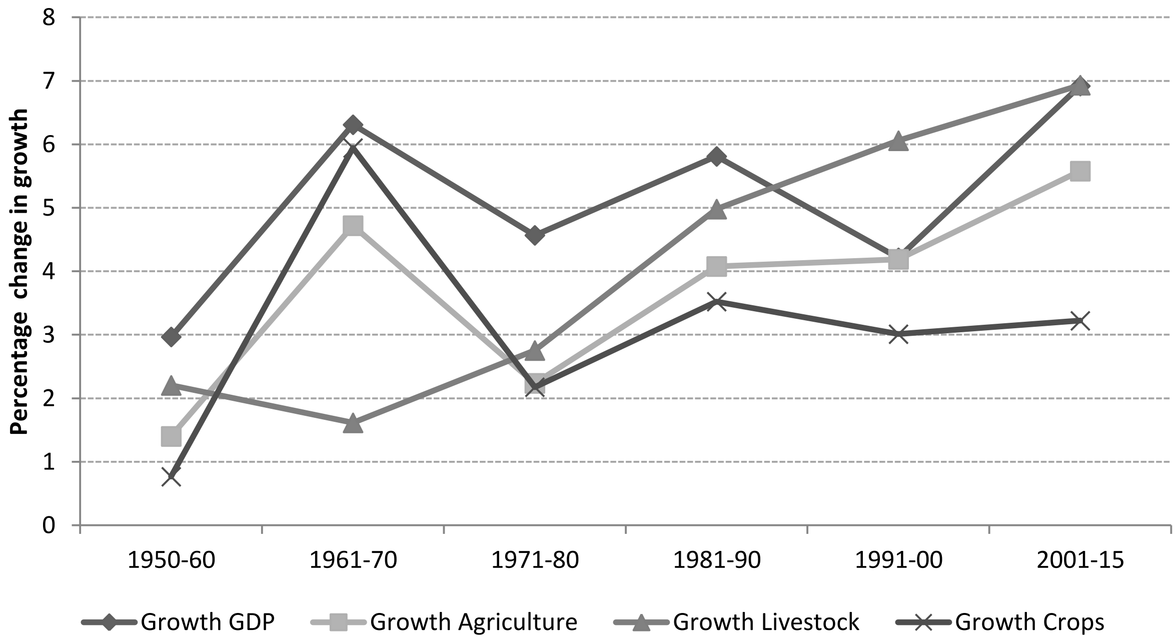
1.1 Introduction

In Pakistan, the growth of agriculture plays a pivotal role in fulfilling the macroeconomic objectives of the country through its forward and backward linkages with other sectors of the economy. Accelerated agricultural growth directly helps to reduce poverty and satisfy the food requirements of the poorer segments of society (Government of Pakistan, 2014). Agriculture makes up a 20.9 percent share of Pakistan's Gross Domestic Product (GDP) and provides job opportunities to 43.5 percent of the labour force, while 60 percent of the rural population depends on the sector. The share of agriculture and agriculture-based processed products makes up 70 percent of the country's total exports (Government of Pakistan, 2015).

Agriculture in Pakistan is a combination of both dairying and cropping production. Livestock contributes 56.3 percent to the value added in overall agriculture and 11.76 percent to the national GDP, while crops account for 36.7 percent of the value added in overall agriculture and 7.6 percent of the GDP. The agriculture sector grew 3.85 percent between 1949 and 2015, with growth rates of 4.31 percent in the livestock sector and 3.12 percent in the cropping sector.

The growth rate of Pakistan's agriculture sector has been uneven over the years. From 1951 to 1960, the growth rate remained at 1.4 percent with a 2.20 percent growth in the livestock subsector and 0.75 percent in the cropping sector, the lowest in any decade. In the following decade, the growth rate of agriculture increased to 4.72 percent due to the Green Revolution. The livestock sector observed a growth rate of 1.61 percent while the cropping sector increased to 5.94 percent in the same decade. Later in the 1970s, the growth rate of agriculture fell to 2.23 percent due to political instability and failures in implementing policies. The livestock sector grew at a rate of 2.75 percent while the cropping sector advanced 2.17 percent. In the 1980s, the growth rate of the agriculture sector rose to 4.07 percent, with a 4.98 percent growth in livestock and 3.52 percent growth in the cropping sector. In the next decade, growth in the agriculture sector remained at 4.19 percent due to extreme floods and political instability in the country. The livestock sector grew at 6.05 percent while the cropping sector grew at 3.22 percent. From 2000 to 2015, the growth rate of agriculture rose to 5.57 percent, with 6.96 percent growth in the livestock sector and 3.22 percent growth in the cropping sector (Figure 1.1).

Figure 1.1 Growth in GDP, agriculture and its sub-sectors in Pakistan



Data source: (Economic survey of Pakistan, 1980; 1988; 1999; 2002; 2015)

It is evident that the livestock sector plays an important role in the country's economy. In the livestock sector, milk production is the most important component, and value of milk alone exceeds the combined value of all major crops. Milk production is practiced by approximately 150 million households worldwide, keeping 363 million milking cows and buffalos (FAO, 2012; IFCN, 2013). In Pakistan, 8.5 million households are dependent on livestock for their livelihood, keeping 5 million milking cattle and buffalos which produce 40 billion liters of milk with a 3.89 percent annual growth rate (Figure 1.2); this makes Pakistan the fourth largest producer of milk in the world (GOP, 2013, FAO, 2014). In Pakistan, 35 million people are engaged in livestock sector and earn approximately 30-40 percent of their income from livestock (IFAD, 2013). It also serves as security for farmers against crop failure.

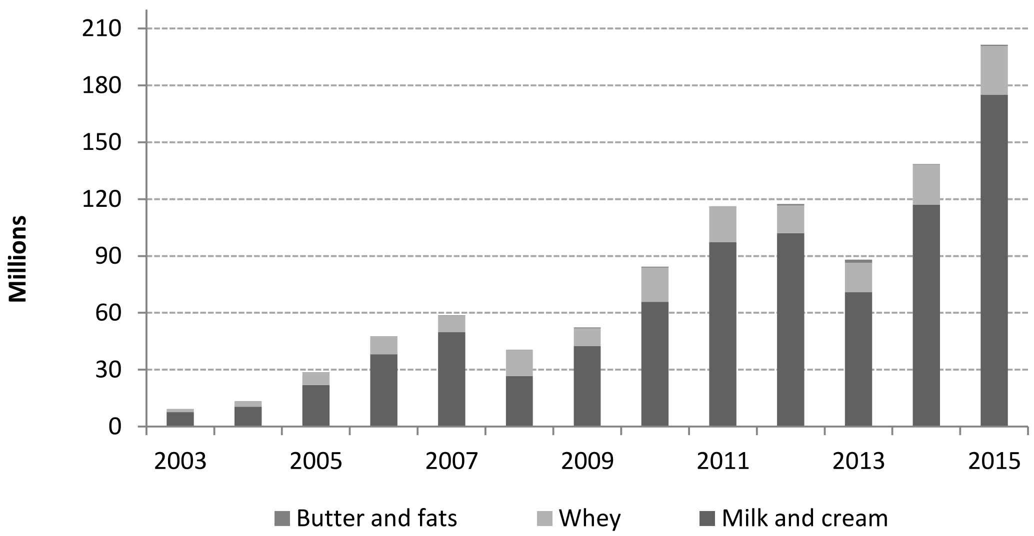
Out of the 40 billion liters of milk produced in Pakistan, 31.76 billion liters (80 percent) are available for human consumption (Rana & Mumtaz, 2012). Nearly 40 percent of this is marketed, and the remaining 60 percent is consumed by rural households (Zia, 2006). Rural dairy farms contribute 80 percent of the total milk marketed, while the remaining is produced by urban and peri-urban farms.

Figure 1.2 Annual milk production and growth in Pakistan

Data source: (Economic Survey of Pakistan, 1985-86; 1990-91; 2013-14)

Milk collection and its processing are major challenges of dairy sector of Pakistan. Milk is collected by two main channels; traditional channels, where milkmen or vendors are major player who collect milk at farm gate and distribute among urban consumers, sweet shops and consumers, while modern milk supply channels collect milk through their milk collection units in rural areas. More than 90 percent of the milk is marketed through informal channels (such as the milkman or through a direct supply to the consumer), while less than 10 percent is delivered to the formal processing industry (Aslam & Kamal, 2012). Of the total milk sold, 15 percent is wasted en route-to-market due to a lack of proper cooling, storage, and transport systems (Fakhar & Walker, 2006). Although Pakistan has very low levels of milk processing but due to expanding urban population, traditional milk supply channels are unable to cope with increasing demand and there is enormous scope of modern milk supply channels. The number of modern supply channels in Pakistan increase from 2 in 1990s to 21 in 2010. However, despite being the fourth largest producer of milk in the world with an annual production of 40 billion litres (Government of Pakistan, 2014), Pakistan spent about US$ 201.45 million out of its scarce resources on imports of milk and milk products in 2015(Comtrade, 2016). Pakistan's imports of milk and products have increased on average at 18 percent from 2003 to 2015 (Figure 1.3).

Figure 1.3 Milk imports of Pakistan



Data Source: (Comtrade, 2016)

Although Pakistan's agriculture sector performs good but it still has many challenges of productivity and efficiency. To achieve better productivity requires transition of dairying and cropping sectors from traditional and subsistence to modern and commercialized farming. It demands adequate availability of inputs like improved seeds, modern irrigation practices, balanced use of fertilizers, agricultural credit, mechanization, farmers' training, improved infrastructure and opportunities of investment in agro-based industry, agricultural research and efficient milk marketing channels.

The concept of competitive market economy has brought revolutionary changes in food production and its marketing all over the world and integrated food supply channels are the fastest growing and prominent market phenomenon (Delgado, 1999; Lundvall, Joseph, Chaminade, & Vang, 2009). Now a days traditional and modern supply channels provide diverse, accessible, and nutritious foods to consumers in urban and rural regionally and globally. Modern supply chains ensure availability of perishable food items without destroying its nutrient. A well designed food supply channels could help to reduce wastage and may ensure timely availability of food items though out the country.

This research is focused on the estimation of technical efficiency and productivity of dairy farmers in Pakistan. We have selected province of Punjab for field research. The main reasons for selecting Punjab are its higher share in livestock and agriculture production of Pakistan and an expanding network of modern milk supply channels in the province. In the section 1.2 we describe the research area and in section 1.3 we explain the research objectives and research topics.

1.2 Research area description

Over time, the structure of agriculture in Pakistan has been progressively changing. The share of major and minor crops has gradually declined while share of livestock has significantly increased. Over the past 20 years, the share of the livestock sector in Pakistan has grown from 30 percent in 1994 to about 56 percent in 2014 (Government of Pakistan, 2014). The livestock sector grew at a rate of 6.7 percent during this time; cropping sector had a growth rate of 3.4 percent over the same period. In Pakistan, the province of Punjab has the largest share of livestock in the country. The word Punjab literally means “land of five rivers.” It has an area of 205345 square kilometres and has 36 districts. Punjab is Pakistan’s largest province both in terms of population (56 percent) and share in national GDP (59 percent). The province has about 29 percent of the total reported land area of Pakistan, with 57 percent of the total cultivated land and 69 percent of the country’s total cropped area. Agriculture sector contributes 28 percent to the output of Punjab and provides employment to roughly 40 percent of the province’s work force. Table 1.1 describes the demographics and land utilisation statistics of Punjab. Punjab has population of 99 million people with 31 percent of population in urban areas and 69 percents in rural areas. In Punjab, 72 percent of land is arable and 89 percent of arable land is under cereals and cash crops while 11 percent of land is under fodder crops.

In cereals crops, wheat and rice are major crops while cotton and sugarcane are important cash crops in Punjab. Punjab contributes to a major share of the country’s cropping sector by providing about 71.6 percent of cotton, 76 percent of wheat, 97 percent fine aromatic rice (Basmati), 64.8 percent of sugarcane, and 81.3 percent of maize to Pakistan’s national food production. Among fruits, Punjab’s share in mango production accounts for 75.5 percent, while its citrus share is more than 96.8 percent, and contributes 75.6 percent in guava's total national production (BSP, 2015).

Table 1.1 Demographic and land utilisation data of research area

Demographics	***(Thousand)***
Population	99794
Urban	31837
Rural	67957
Men	51204
Women	47801
Land utilisation	***(Thousand hectares)***
Cultivated area	12738
Uncultivated area	4942
Total reported area	17680
Major and minor crops	14530
Fodder crops	1835

Data source: (Punjab Development Statistics, 2015)

Livestock is an important sub-sector of agriculture and Punjab has 56 percent of the total national herd which includes 65 percent of the total buffalo population and 49 percent of the total cattle population in addition to almost a 65 percent share of the total milk in the country. Table 1.2 describes the growth in cattle and buffalo population in Punjab. Buffalo is important milking animal in Punjab which accounts for 54 percent of herd in Punjab. Pakistan is the world second largest producer of buffalo milk and Punjab has the famous breed of buffalo called Nili-Ravi. Cattle accounts for 46 percent in herd and Punjab has well-known indigenous breed of cattle called Sahiwal.

Table 1.2 Population of cattle and buffalo in Punjab

(Thousand)

Type	**1990**	**1996**	**2000**	**2006**	**2010**
Cattle	7665	9382	8485	14412	13204
Buffalo	10863	13101	13170	17747	16019
Total	18528	22483	21655	32159	29223

Data source: (Punjab Development Statistics, 2015)

Considering the importance of the area, we collected data from twelve districts[1] of Punjab from a total of 345 farmers between February and April 2013. Information was collected on outputs, inputs, and socioeconomic factors of dairy-crop farmers. Figure 1.4 shows the location of Punjab and data collection points (village location) in the research area.

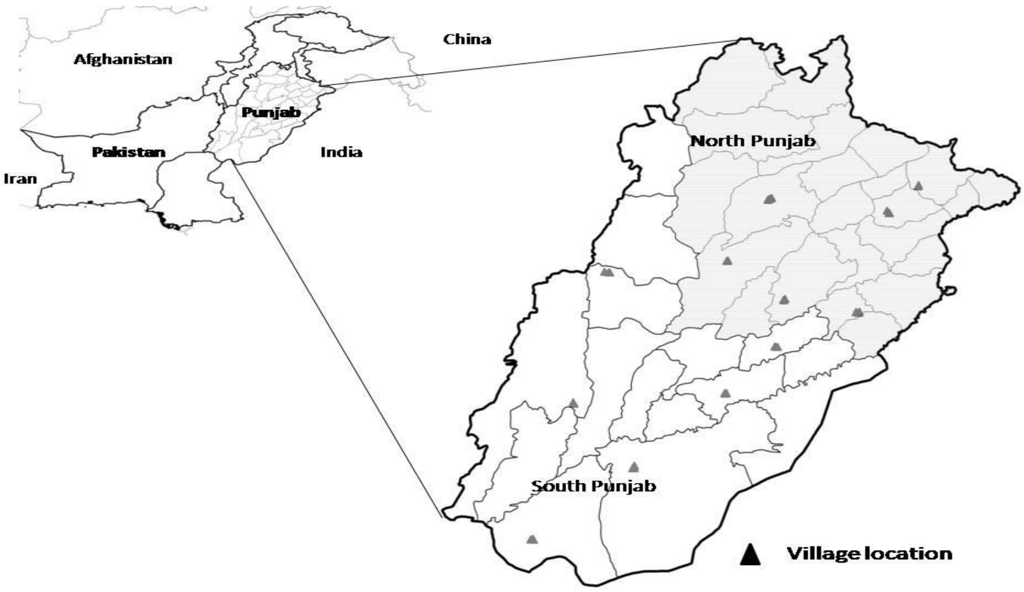


Figure 1.4 Location of Punjab with geographical position of dairy farms

Source: Made by author with the help of QGIS software

[1] Sialkot, Okara, Gujranwala, Sargodha, Jhang, Faisalabad, Sahiwal, Vehari, Bahawalpur, Rahim Yar Khan, Dera Ghazi Khan, Layyah

1.3 Research objectives and topics

We analyse the productivity and efficiency of the dairy sector in Pakistan within single and multi-output frameworks and also investigate the determinants of farmers' participation in different milk supply channels by employing three different methodological techniques: stochastic frontier analysis, the multi-output distance function, and the logit model. This dissertation consists of three essays which are introduced below.

1.3.1 Role of extension services in efficiency of market oriented dairy farmers in Punjab, Pakistan

This research paper investigates the economic performance of market oriented dairy farmers and the role of extension services and other determinants of technical efficiency of farmers in Pakistan. The paper starts with some background of the dairy sector in Pakistan and describes the data structure. We use the stochastic production frontier approach to estimate the production performance of dairy farmers. The results show that the mean technical efficiency is 85 percent, indicating that output can be increased by 15 percent through enhancing technical efficiency of the dairy farmers. The study reveals that extension services increase the technical efficiency of dairy farmers by imparting better management and diseases control skills. The efficiency of farmers is also found to increase with the possession of crossbred and imported livestock and higher experience. The study recommends extended extension services, quality training programmes, the provision of improved crossbred cattle and buffalos, and measures to control the indiscriminate cross breeding of cattle and buffalo to ensure good quality breeds.

1.3.2 Efficiency of Pakistan dairy and agriculture sector: An output distance function approach

This study examines the economic performance of dairy-crop farmers in Pakistan. The study reviews changes in the structure of the country's dairy and cropping sectors. A cross-section data set of 323 dairy-crop farmers is used to measure elasticities of input substitution, complementary effects, and technical inefficiency of farmers by employing a translog output distance function. The results show significant substitutions effects between labour and land, and complementary effects between labour and irrigation. The overall technical efficiency of the dairy-crop farmers is estimated to be 79 percent; this implies that by eliminating technical inefficiencies, output can be increased by 21 percent. The differences in efficiency are explained by extension services, credit, age, experience, and rented land. Target-oriented extension programmes, regulated rental markets and the provision of easy access to credit would be effective in reducing technical inefficiencies.

1.3.3 Choice between traditional and modern milk supply channels by farmers in Punjab, Pakistan: A logit regression approach

This study focuses on investigating the factors which influence farmers' choices of milk marketing channels in Punjab, Pakistan. The study provides background on the changing milk marketing structure in Pakistan. A binary logit model is used to test factors affecting farmers' decisions between traditional and modern milk supply channels. The empirical results indicate that the volume of milk sold, improved cattle breeds, milk prices, distance to milk collection units, and payment methods are all significant factors that influence the choices of farmers between the two market channels. The quantity of milk sold and improved cattle breeds are both important factors leading to the selection of modern supply channels. However, milk prices, distance to milk collection unit, and long payment periods discourage farmers to participating in modern channels. The study suggests that to increase milk collection, the provision of advanced dairy technology, institutional support, and investment in rural infrastructure to improve access to remote farmers could enhance the capability of farmers to manage their resources, and hence could shift farmers towards commercialisation.

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Chapter 2

Role of extension services in efficiency of market oriented dairy farmers in Punjab, Pakistan

This study investigates the technical efficiency of market oriented dairy farmers in Pakistan using the stochastic production frontier function approach. The results show that the mean technical efficiency is 85 percent, indicating that output can be increased by 15 percent by enhancing the technical efficiency of the dairy farmers. The study reveals that extension services increase the technical efficiency of dairy farmers by imparting better management and disease control skills. The possession of crossbred and imported livestock and higher experience of farm managers also increase the efficiency of farmers. Extended extension services are recommended, alongside quality training programmes, the provision of improved crossbred cattle and buffalos, and measures to control the indiscriminate cross breeding of cattle and buffalo to ensure good quality breeds. It is also necessary to develop infrastructure in rural areas to aid the expansion of modern milk supply networks to remote areas.

2.1 Introduction

Livestock is an important sub-sector of agriculture which plays a significant role in both subsistence and the economic development of Pakistan. It contributes 11.76 percent to the national GDP and accounts for 55.5 percent of agricultural value added. Nearly 30-35 million people are affiliated with the livestock sector and earn 30-40 percent of their income from it (Government of Pakistan, 2013). The gross value addition of the livestock sector at current factor costs has increased by 15.01 percent - from Rs[2] 3138 million (US$ 29.75 million) in 2013-14 to Rs 3609 million (US$ 34.21 million) in 2014-15 (Government of Pakistan, 2015). Milk production is the most important component of livestock. Its growth is 3-4 percent per annum and annual demand has increased by 15 percent (Jano, 2011). Loose milk penetration in food baskets is as high as 93 percent and almost 30 percent of household expenditure is on milk and milk products (Wynn et al., 2006). However, Pakistan's population has increased from 65 million to 180 million over the past three decades with an estimated growth rate of over 2 percent, and is expected to grow to 234 million by 2025. This has raised the gap between milk demand and supply to 3.5 million tons per year and it could potentially reach 55.48 million tons by 2020 (FAO, 2013). Despite being the world's fourth largest producer of milk with an annual production of 40 billion litres (Government of Pakistan, 2014). Pakistan spent about US$ 93.98 million out of its scarce resources on importing milk and milk products in 2011 (Government of Pakistan, 2011).

The dairy population in Pakistan increased from 56.9 million in 2006 to 76.8 million in 2014 with an annual growth rate of 2.87 percent. Meanwhile, milk production increased from 32.13 million tons to 40 million tons, with an annual growth rate of 2.26 percent in the same period. The cattle population increased at 2.87 percent per annum and buffalo at 2.59 percent, while the milk growth of cattle was 2.53 percent and buffalo was 2.06 percent over the same period (FAO, 2014; Government of Pakistan, 2015). Rural dairy farms contribute 80 percent of the total milk marketed, while the remaining amount is produced by urban and peri-urban farms. More than 90 percent of milk is marketed through informal channels (such as the milkman or direct supply to consumer), while less than 10 percent is delivered to the formal processing

[2] Rs = Pakistani Rupee(s)

industry (Aslam & Kamal, 2012). Of the total milk sold, 15 percent is wasted en route to market due to lack of proper cooling, storage, and transport systems (Fakhar & Walker, 2006).

Nevertheless, the dairy industry in Pakistan is based on conventional farming which faces problems due to the poor genetic potential of animals for milk production, low quality feed, improper and traditional marketing channels, conventional management practices, and poor extension services (Sarwar, Khan, Nisa, & Iqbal, 2002).

The Pakistani government has implemented policies to increase farm competiveness and milk production. In its second five year plan (1955-60), the government planned to purchase milk from specialised dairy farmers and vendors and sell it to consumers after pasteurisation. It also suggested making cooperatives of vendors to transport milk to cities. In the 1970s and early 1980s, the government offered incentives to private milk supply channels and encouraged investment with the introduction of aseptic packaging material for ultra-high temperature (UHT) treated milk by Tetra Pak Pakistan Limited. The milk processing industry received massive investment in Pakistan, and the private sector established 23 milk processing plants. However, the supply of fresh milk to the processing industry did not improve (Anjum, Lodhi, Raza, Walters, & Krause, 1989). In 1985, the government imported purebred Holstein Freisian and Jersey cattle from the USA and conducted research until 2001 to evaluate the environmental factors affecting productivity of animals and to improve the genetics of local cattle (Lateef, Gondal, Zaheer, Mustafa, & Bashir, 2008).

However, in the all the previous efforts government did not focus on extension and veterinary services in dairy sector of Pakistan. In 2006, the government developed a project called *doodh darya* (White Revolution) to enhance milk production and to bridge the gap between domestic demand and supply with the possibility of being an exporter in the long run. This aimed to invest in both dairy infrastructure and human capital by establishing model dairy farms to introduce modern farm management techniques, mobile milk collection units to enhance the capacity of the milk supply chain, improved and imported semen to improve herd genetics, free vaccination campaigns, vocational and training facilities for dairy technicians and extension workers, and training programs for farmers. The government provided soft loans to farmers and introduced a zero-rated tax regime for value added dairy products to increase investment in the milk processing industry (Fakhar & Walker, 2006).

After shift in focus the number of veterinary hospitals increased from 527 in 2006 to 566 in 2013 in Punjab and number of veterinary dispensaries increased from 775 in 2006 to 1654 in

2013 (BSP, 2015). The government ensured to provide extension and veterinary services to remote dairy farmers through trained staff.

Several studies have assessed the efficiency of production in agriculture using the frontier production technique, most notably Battese, Malik, & Gill (1996), Battese & Coelli (1995), Brümmer (2001) *etcetera*. Numerous studies have also been conducted to investigate the technical efficiency of dairy farmers in many countries: Heshmati & Kumbhakar (1994) Cuesta (2000), Alvarez & Arias (2004), Bravo-Ureta et al. (2008), Cabrera, Solís, & del Corral (2010), Nganga, Kungu, Ridder, & Herrero (2010), Mor & Sharma (2012) and Uddin, Brümmer, & Peters (2014) . Mor & Sharma (2012) and Nakanwagi & Hyuha (2015) found that the possession of crossbred livestock affects the efficiency of dairy farmers positively and significantly. Ahmad et al. (2012), O'Neill, Matthews, & Leavy (1999) and Saldias & Cramon-taubadel (2012) found that the extension and advisory services increased the technical efficiency of dairy farmers.

Despite the importance of the dairy sector to Pakistan's economy, we are aware of only two studies on the technical efficiency of dairy farmers in Pakistan: Burki & Khan (2011); Sadaf & Riaz (2012). Both of these studies have focused on the effect of modern milk supply chains on technical efficiency of farmers. Burki & Khan (2011) used stochastic frontier analysis to assess the impact of modern milk supply chains in the milk districts of Punjab, and found a positive effect on technical efficiency with a mean technical efficiency of 0.79. Sadaf & Riaz (2012) used Data Envelopment Analysis (DEA) techniques to assess the technical and allocative efficiencies of dairy farmers in the Sargodha district. They found that efficiency is positively affected by the herd size, and negatively affected by the size of the operational land area. They found that the mean technical efficiency of the dairy farmers under variable returns to scale was 0.89 while the scale efficiency was 0.94.

Access to extension and veterinary services, on-farm training, and improvement in herd breed are critical determinants of competitiveness in the dairy sector. However, little is known about the impact of access to extension and veterinary services and herd breed structure on farmers in Pakistan. The purpose of this study is to cast a light on the impact of extension and veterinary services and herd breed structure on the technical efficiency of market oriented dairy farmers in Pakistan. Using the cross sectional data from 2013, we address the following questions:

Is there evidence that extension and veterinary services cause an increase in technical efficiency?

Does the herd breed structure influence the technical efficiency?

This paper gives estimates of technical efficiency of market oriented dairy farmers based on a province-wide sample of Punjab. It identifies the factors influencing the technical efficiency of dairy farmers and is a valuable exercise to provide further policy recommendations.

2.2 Methodology

Techniques of efficiency measurement based on parametric or non-parametric functions are traced back to the work of Farrell (1957). Later, Aigner, Lovell, & Schmidt (1977) and Meeusen & Van Den Broeck (1977) developed stochastic production frontiers based on the econometric estimation of parametric functions. Comprehensive work on the stochastic frontier model is explained in Bauer (1990); Coelli (1995); Kumbhakar & Lovell (2000); and Coelli, Rao, O'Donnell, & Battese (2005). The stochastic frontier production function specifies output variability using a composed error term ε_i, in which additional random error, v_i (noise effect), is added to the non-negative random variable, u_i (inefficiency effect). The following equation expresses the SFA model for a cross sectional data.

$$Y_i = f\ (X_i; \beta) \exp(\varepsilon_i)$$
$$\exp(\varepsilon_i) = \exp(v_i) \exp\ (-u_i) \quad (1)$$

Y_i denotes the level of output for observation (farm) *i*. f(X_i; β) is a relevant function (Cobb-Douglas or translog) of the row vector of inputs X_i , and β is a vector of unknown parameters. The error term ε_i, composed of two independent parts, v_i and u_i , such that $\varepsilon_i = (v_i - u_i)$. v_i is a pure random factor that represents external shocks and factors not under the control of farmers. v_i is supposed to be an *i.i.d.* (independently and identically distributed), normal random variable with zero mean and constant variance σ^2_v, $[v_i \sim N\ (0, \sigma^2_v)]$. $u_i \geq 0$ is a systematic, non-negative random variable which accounts for inefficiency and is associated with farm-specific factors. Estimation of equation (1) hinges upon distributional assumptions regarding the two error terms. Various distributional assumptions are available in the literature for the

u_i. However, we use the model of Battese & Coelli (1995) which assumes that u_i follows a truncated normal distribution with mean μ_i, and variance σ^2_u,[$u_i \sim N^+(\mu_i, \sigma^2_u)$]

$$u_i = \delta_0 + \delta Z_i \qquad (2)$$

Zi is a Q×1 vector of explanatory variables that could influence the efficiency performance of farmers; this may include socioeconomic and farm management characteristics. δ is an associated vector of unknown parameter to be estimated.

The frontier of the production function is defined by the "best practice" farms which exhibit the maximum potential output for a given set of inputs. Thus the technical efficiency TE$_i$ of the $_i$th farm is expressed as a ratio of the observed output to the corresponding potential output. This is written as:

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(X_i\,;\beta)\,.\ \exp(\nu_i - \mu_i)}{f(X_i\,;\beta)\,.\exp(\nu_i)} = \exp\,(-\,\mu_i) \qquad (3)$$

Where Y_i is always $\leq Y_i^*$ and the corresponding output-oriented technical efficiency measure, TEi = exp($-u_i$) ∈ [0,1], which shows that if $u_i = 0$, the production lies on the frontier and hence is technically efficient. However, if $u_i > 0$, the farm lies below the frontier line and is technically inefficient. The output-oriented approach is suitable in agricultural settings because input choices are made at the start of the production period, hence input levels can be considered to be predetermined. Since production takes a considerable amount of time to complete in an agricultural setting, the correlation between the stochastic error term and the predetermined input variables can be considered to be zero or very small (Griliches, 1963). In such a case, the direct estimation of equation (1) for the production frontier function does not suffer from simultaneous equation bias (Dinar, Karagiannis, & Tzouvelekas, 2007; Zellner, Kmenta, & Drèze, 1966). Moreover, Caudill & Ford (1993) and Wang (2002) argued that two stage estimation can lead to biased estimators. We use an alternative approach to measure the full model based on the studies of Kumbhakar, Ghosh, & McGuckin (1991), Huang & Liu (1994) and Battese & Coelli (1995).

Battese & Corra (1977) proposed that by considering a distributional assumption of the random errors, the single-step estimation of the parameters of models (1) and (2), and the model of technical efficiency (3), can be estimated in terms of the parameterisation: $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2 = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$. The value of the γ parameter lies between zero and one. A value of $\gamma = 1$ shows that the deviations from the frontier are entirely due to technical inefficiency, whereas a value of $\gamma = 0$ indicates that the deviations from the frontier are entirely due to noise effects.

2.3 Data description

Pakistan has a total of four provinces with Punjab the largest, in terms of both population (56 percent) and share in national GDP (59 percent). The agricultural sector contributes 28 percent to the total output of Punjab and provides employment to roughly 40 percent of the work force. Livestock is an important sub-sector of agriculture and Punjab has 56 percent of the total national herd, including 65 percent of the total buffalo population and 49 percent of the total cattle share; it also accounts for nearly 70 percent of the total milk produced in Pakistan. Considering the importance of the area, we collected data from two regions of Punjab province in February-April 2013: South Punjab and North or North Punjab. These regions are based on political and cultural divisions in the province. Data were collected through the random selection of farmers from twelve districts of two regions (six districts from each region); from each district, data were collected from one randomly selected union council. In the southern region, we collected data from 171 farmers, while 174 farmers were interviewed in the northern region. We collected data from farmers who were selling milk since more than one year. A well-structured questionnaire was prepared to acquire relevant information on socioeconomic characteristics, milk marketing choices, farming practices, outputs, inputs, and prices. As a primary step in the data collection, we conducted a pilot test to corroborate the appropriateness and suitability of the questionnaire in the field. We revised the questionnaire considering the errors detected through the pilot survey. Variables of outputs, inputs, and farm-specific characteristics considered in the study are described below and summarised in Table 2.1.

The dependent variable Y_i is defined as the gross quantity of milk produced (Litres) at a farm during the year. The vector X_i comprises six inputs: green fodder (gfodd) is measured by the total quantity of green fodder in kilograms. Dry fodder and concentrates (dfconc) is measured by the total quantity of dry fodder (Q_{df}) and concentrates (C_{onc}) in kilograms. Dry fodder and concentrates are added as a single variable in the model. We took the price ratio of concentrates and dry fodder ($P_{con}/P_{df}= P_x$) and multiplied it by the quantity of dry fodder ($Px*Q_{df} = Q_x$) and then added it to the quantity of concentrates (Dry fodder and concentrates = $Q_x + Q_{conc}$) to get a single variable. Veterinary services (vetservices) are measured in rupees (Rs.) and calculated from expenses on vaccinations, artificial insemination, and veterinary services. Capital (Rs.) is the user cost of machinery, vehicles and expenditures on other fixed costs adjusted for depreciation and interest rates. Labour is measured in working hours based on the reported shares of time spent by family members (hflabor) and hired labour on different activities. Some dairy farmers do not use family labour, so following Battese (1997), an additional dummy variable (Dummy Family labor (dfl) = 1 if dfl > 0) is used to avoid biased parameter estimates. Livestock is measured in terms of peak milk animals (pmcattle) at any time during the year.

We specify a vector Z that includes a number of additional variables which represent the determinants of technical efficiency. These variables account for socio-economic characteristics, farm management decisions, and milk market infrastructure based on the characteristics of the production system. Age, experience and education represent the state of human capital. Age is expected to have negative effect on the technical efficiency of farmers, as older farmers tend to have small and subsistence production due to labour intensive structure of dairying. Experience is expected to increase the technical efficiency of farmers.

Age represents the age of the farm manger in years. Experience (exp) is the number of years engaged in the dairy business. Education is hypothesized to have either positive or negative association with the technical efficiency. Farmers with higher levels of education tend to have less time for dairying activates as compared to other duties. We have included the level of education as a determinant of technical inefficiency. Education (edu) represents the number of formal years of schooling of the farm manager. We have ranked the formal education as none $\Longrightarrow$ 0; primary level $\Longrightarrow$ 1; secondary level $\Longrightarrow$ 2; higher secondary level $\Longrightarrow$ 3; bachelor level $\Longrightarrow$ 4; and master level and above $\Longrightarrow$ 5.

Extension services create awareness among farmers about new technology and modern farms practices. Generally, extension services are considered to have positive effect on the technical efficiency of farmers. However, quality and focus of extension services defines the outcome of such programmes. Lopez (1996) argued that extension programmes in Chilian agriculture increased the production through greater use of inputs rather than better use of inputs to enhance productivity. Access to veterinary and extension services (vetvisit) represents the visits of veterinary and extension officers as well as farmers' visits to the veterinary station. Veterinary and extension services in Pakistan are provided by the district livestock department through its trained staff; they provide services of vaccination, artificial insemination, and extension services on disease control and herd management. To capture the effect of extension visits paid to neighbouring farmers on the technical efficiency of farmers, we construct a variable (neighbourvisits) by adding the extension visits paid to three neighbouring farmers. We trace the three neighbouring farmers using GPS locations of the nearest farms.

Table 2.1 Summary of the variables in the frontier and inefficiency models

Variable	Unit	Mean	Std. Dev.	Min	Max
Frontier Production function model					
Milk (output)	Liters	13734	10164.22	1686	76010
Capital	Rupees	8063	4584.44	1079	28273
Green fodder	Kg	167662	107345.9	25530	774840
Dry fodder and Concentrates	Kg	63307	58861.41	5517	617200
Veterinary services	Rupees	7346	7565.18	600	85000
Labour	Hour	3453	1269.98	1369	8849
Family labour	Hour	1681	1492.27	0	7787
Hired labour	Hour	1768	1873.20	0	8760
Peak milk cattle	Numbers	5.91	4.20	1	38
Total herd	Numbers	18.16	12.19	2	62
Technical inefficiency model					
Education	Levels	2.03	1.42	0	5
Age	Years	45.14	11.00	21	75
Experience	Years	16	8.78	2	45
Extension visits	Numbers	12	8.14	1	60
Neighbours' extension visits	Numbers	38.28	15.63	8	120
Crossbred and imported cattle	Percentage	27	28.92	0	100
Processor	Dummy	0.24	0.44	0	1

Exotic and crossbred cattle are expected to increase the technical efficiency of farmers. They require more care and are sensitive to local conditions, which may press farmers towards better management of their farms. The cross and imported cows share (shcic) is the percentage of cross and imported cows in the total herd. Modern milk supply channels require high quality standards and continuous supply of milk and also provide farmers with more stable milk prices which may increase the technical efficiency of farmers. The milk sale marketing strategies (processor) of the farmers are captured as 1 if milk is sold to the processing unit and 0 otherwise.

2.4 Empirical model

Based on the theoretical discussion in the section above, we lay out the econometric specification of the stochastic production frontier and inefficiency model in the following section. To estimate the stochastic production frontier, both Cobb-Douglas and Translog functions are used to specify the stochastic frontier. Both functions assume that every input in the production function is essential for dairy production, thus satisfying the strong essentiality property of a production technology. Both functional forms satisfy the monotonicity property, provided that the first-order coefficients are non-negative. We use the generalised likelihood ratio tests to specify the correct functional form in our study. Likelihood ratio tests confirm that equation (1) is best specified in a log-linear Cobb-Douglas functional form.

$$\begin{aligned} \ln(\text{milk/gfodder}) = {} & \beta_0 + \beta_1 \ln(\text{pmcattle/gfodder}) + \beta_2 \ln(\text{dfconc/gfodder}) \\ & + \beta_3 \ln(\text{vetservices/gfodder}) + \beta_4 \ln(\text{hflabor/gfodder}) + \beta_5\, \text{dfl} \\ & + \beta_6 \ln(\text{capital/gfodder}) + v_i \;\; u_i \end{aligned} \tag{4}$$

The technical inefficiency model in equation (2) is specified by

$$\begin{aligned} \mu_i = {} & \delta_0 + \delta_1\, \text{age} + \delta_2\, \text{exp} + \delta_3\, \text{edu} + \delta_4\, \text{vetvisit} + \delta_5\, \text{shcic} \\ & + \delta_6\, \text{processor} + \delta_7\, \text{neighbourvisits} \end{aligned} \tag{5}$$

Before heading towards final estimation, we have tested the following hypotheses by using the generalised likelihood ratio test (Table 2.2).

$H_0 : \beta_{ij} = 0$, specifies that the Cobb-Douglas function is a statistically valid representation of the data.

$H_0 : \beta_\rho = 0$, states that there are no technological differences between the northern and southern regions of Punjab.

$H_0 : \gamma = \delta_0 = \delta_1 = \cdots = \delta_7 = 0$, specifies that inefficiency effects are absent from the model at every level.

$H_0 : \delta_1 = \delta_2 = \cdots = \delta_7 = 0$, states that farm-specific factors do not influence the inefficiencies.

Table 2.2 Hypothesis tests for the adopted model and statistical assumptions

Null hypothesis	$L(H_0)$	λ	d.f.	$\lambda^2_{0.05}$	Decision
1. $H_0 : \beta_{ij} = 0$	-47.61	22.37	21	24.99	Not rejected
Testing the specification of the technical inefficiency model					
2. $H_0 : \beta_\rho = 0$	-7.53	5.94	16	26.29	Not rejected
3. $H_0 : \gamma = \delta_0 = \delta_1 = \cdots = \delta_n = 0$	-47.6	2.21	1	1.64*	Rejected
4. $H_0 : \delta_1 = \delta_2 = \cdots = \delta_7 = 0$	-47.61	80.17	7	14.06**	Rejected

*Critical values are taken from Kodde & Palm (1986). For this value, the statistic λ has a mixed χ^2 distribution.

2.5 Results and discussion

The generalised likelihood ratio test specifies that the hired labour and its dummy are not statistically significant and have the wrong sign; as a result, we drop these from the final estimation. The second null hypothesis for specification of the functional form cannot be rejected. This concludes that the Cobb-Douglas function is a more adequate representation of the data than the translog frontier. The null hypothesis on technological homogeneity between the two regions cannot be rejected. This implies that both regions share the same technology, so we pooled the data for further estimation. The test for the absence of inefficiency effects from the model is rejected. This implies that the technical inefficiency effects exist in this model. The last null hypothesis that firm specific factors do not influence the technical inefficiency is also rejected. Consequently, the variables specified in the technical inefficiency model are important to explain the variation in the production function of dairy farmers in Pakistan, although some of the variables have no statistically significant influence.

2.5.1 Frontier model estimates

Maximum-likelihood estimates of the production frontier are presented in Table 2.3. All inputs are measured in logarithmic form, so estimated coefficients represent the partial production elasticities. The expected elasticities of the input variables are significantly positive, with the exception of the coefficient of the dummy for family labour, which is statistically insignificant. This means that capital, dry fodder and concentrates, veterinary expenses, family labour, and milk cattle (buffalo and cow) all have an influence on the dairy production system in Pakistan.

Table 2.3 Cobb-Douglas stochastic frontier model estimates

Variables	Parameters	Coefficients	Standard Error
Constant	β_0	3.60***	0.50
Peak milk cattle/gfodder	β_1	0.533***	0.05
Dry fodder and concentrates/gfodder	β_2	0.139***	0.03
Veterinary services/gfodder	β_3	0.062***	0.02
Family labour/gfodder	β_4	0.010**	0.00
Dummy family labour	β_5	-0.007	0.03
Capital/gfodder	β_6	0.032	0.03
Log-likelihood		-7.53	
Gamma		0.28	

* p<0.10, ** p<0.05, *** p<0.01

Cattle have the highest effect on production levels, with an estimated elasticity of 0.53. This indicates that a 1 percent increase in the number of milk cattle results in an estimated increase of 0.53 percent in milk production. Green fodder produces the next highest elasticity (0.22), followed by dry fodder and concentrates (0.13), capital (0.03), veterinary expenses (0.06), and finally family labour (0.01).

2.5.2 Technical inefficiency model estimates

The results of the technical inefficiency model are presented in the Table 2.4. The coefficient of age is significantly positive, showing that older dairy farmers are more technically inefficient than younger ones who are progressive and interested in the implementation of modern techniques and technologies. The dairy sector is Pakistan is labour intensive, leaving older farmers at a disadvantage as many lack the physical ability to manage dairy operations. Coelli & Battese (1996) also argue that older farmers are risk averse and reluctant to adopt modern practices and technologies. This finding is consistent with the results of Singh & Sharma (2011) which show that older farmers are less efficient in Indian dairy farming; Likewise, Nganga et al. (2010) find that age has a positive association with technical inefficiency for milk producers in Kenya.

The coefficient of experience is significantly negative, indicating that farmers who possess more dairy experience are expected to be more efficient as they could better manage their enterprises and are anticipated to cope better with crisis management. During the field survey we noticed that farmers with high dairy experience have better social linkages with other progressive dairy farmers and are up-to-date with modern practices. Similar results are also revealed in studies of Nganga et al. (2010), Mor & Sharma (2012), and Uddin et al. (2014).

Exotic and cross-bred cattle are considered to increase the potential output of dairy farmers and ensure the continuous supply of milk in summer season when buffalo milk production drastically drops. The coefficient of share of cross breeds and imported cows in the herd is estimated to be statistically negative. This implies that owners of cross and imported breed cows are technically more efficient. Exotic and cross-bred cattle also require more care and are sensitive to local conditions which require better management practices to handle these cattle and press farmers to better manage their farms. These findings are consistent with the studies of Mor & Sharma (2012) and Nakanwagi & Hyuha (2015) who find a negative association between the possession of exotic and cross-bred cattle and technical inefficiency, indicating that farmers who possess more cross-bred livestock tend to have a lower technical inefficiency. However, low impact of exotic and cross breeds may suggest that farmers are not aware about modern breeding practices and they may not be able to select suitable breeds for producing improved breeds.

Table 2.4 Technical inefficiency model estimates

Variables	Parameters	Coefficients	Standard Error
Constant	δ_0	-1.547***	0.84
Age	δ_1	0.053***	0.01
Experience	δ_2	-0.114***	0.03
Education	δ_3	0.075	0.11
Extension visits	δ_4	-0.126***	0.03
Share of cross bred and exotic cows	δ_5	-0.010*	0.00
Processor	δ_6	-0.459	0.42
Neighbours' extension visits	δ_7	-0.018*	0.01

* p<0.10, ** p<0.05, *** p<0.01

The coefficient of extension and veterinary services is statistically negative which shows it reduces the technical inefficiencies of farmers. This implies that extension services improve the technical efficiency of dairy farmers through imparting knowledge on modern farming practices and disease control measures, as well as enhancing the management skills of the farmers. These results are consistent with the findings of Ahmad & Iqbal (1999) and O'Neill et al. (1999). However, extension and veterinary services in Pakistan are mainly focused on awareness about disease control measures and enhancing farmers' knowledge regarding breeding techniques. Extension services put little focus on efficient use of inputs and we have found no evidence of increase in productivity due to extension services.

The coefficient of neigbours' extension visits is estimated to be statistically negative. This suggests that extension visits paid to neighbouring farmers play an important role in improving the technical efficiency of farmers as they share their experiences. This might also suggest that farmers with more social contacts are more efficient as they learn from the experiences of neighbouring farmers.

The coefficient of milk sale pattern for the farmers is negative, implying that farmers who sell milk to formal milk processing units are technically more efficient than farmers who sell to traditional channels. However, this association is not statistically significant. One possible rationale could be that the formal milk supply chains have set higher standards for milk purchasing and farmers respond to these standards, which increasing their efficiency. However, modern milk supply chains usually focus on large farmers which do not help to increase the efficiency of farmers across the board.

2.5.3 Technical efficiency

The mean technical efficiency of dairy farmers in Pakistan is 0.85, with a minimum value of 0.47 and maximum value of 0.99; the standard deviation is 0.11 (Figure 2.1). About 40.06 percent of the dairy farmers have technical efficiency indices above 0.90, while 50.66 percent of the farmers range between greater than 0.70 and less than or equal to 0.90. Thus 88.72 percent of the farmers have technical efficiency scores of 0.71 or above. Only 11.2 percent of the farmers have a technical efficiency score below 0.71. The mean technical efficiency of 0.85 indicates that, on average, dairy farmers in Pakistan produce 85 percent of their potential output, given the current state of the technology in the dairy sector. Therefore, milk production can be increased by 15 percent by adopting the best practices of dairy farming.

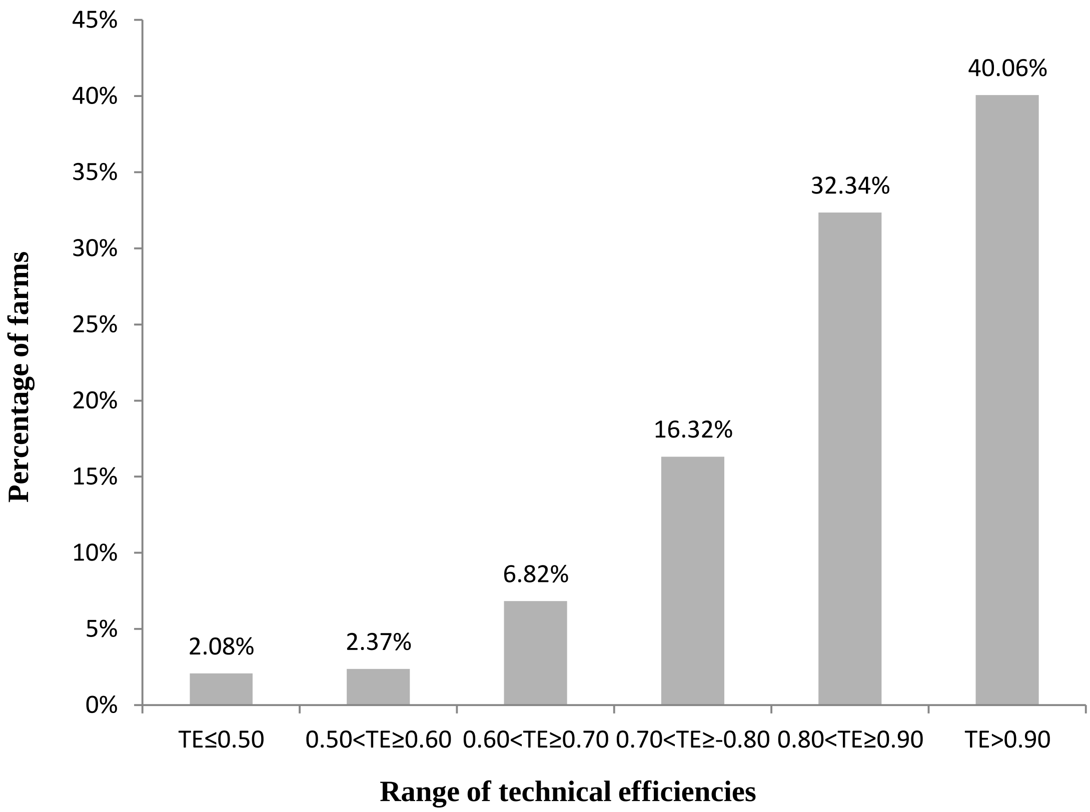


Figure 2.1 Distribution of technical efficiencies of dairy farmers

2.6 Conclusions and recommendations

Dairy sector plays an important role in overall economy of Pakistan. Government of Pakistan introduced many policies in last six and half decades to enhance the productivity and efficiency of dairy sector. However, no significant efforts were made to improve the extension and veterinary services to the dairy sector. After 2000, government introduced several measures to enhance the extension and veterinary services for the dairy sector. We have focused on the effect of extension and veterinary services on technical efficiency of dairy farmers in this changing scenario in Punjab, Pakistan. We estimate a Cobb-Douglas Stochastic production frontier with a technical efficiency model to determine the importance of inputs in dairy production and the farm-specific characteristics that explain the differences in technical efficiency across market oriented dairy farms in Pakistan.

This study shows that dairy farmers in Pakistan exhibit constant returns to scale and, of all the input variables, the number of milking cows has the highest share coefficient, followed by green fodder, and dry fodder and concentrates. The mean technical efficiency is 0.85, implying that the output can be increased by 15 percent without any additional resources. The com-combined effects of all the determinants of the technical inefficiency model are statistically significant in explaining the level and variations in the production of dairy farming in Pakistan, although some of the individual variables have no significant effect.

Extension and veterinary services play an important role to impart knowledge and technical skills to farmers. We have found a significant role of extension and veterinary services in decreasing the technical inefficiencies of the dairy farmers. Studies also shows that extension visits paid to neighbouring farmers also reduce the technical inefficiency of farmers. However, extension and veterinary services in Pakistan are mainly focused on awareness about disease control measures and enhancing farmers' knowledge regarding breeding techniques. It is quite necessary that extension services should also focus on educating farmers about efficient and balanced used of feed to enhance their productivity and reduce cost and create awareness among farmers about modern farm technologies.

We find that share of exotic and cross-bred cattle reduce the technical inefficiency of farmers. Exotic and cross-bred cattle are considered to increase the potential output of dairy farmers and ensure the continuous supply of milk in summer season when buffalo milk production drastically drops. It is quite necessary that farmers should be provided with quality semen and also given better training to select suitable breeds for crossing.

We have found that variable related to human capital like experience increases the technical efficiency while age and education reduces the technical efficiency of the dairy farmers. We have found no significant effect of modern milk supply channels on the technical efficiency of dairy farmers. This may suggest that although modern milk supply channels have strict quality standards and demand continuous supply of milk but they do not train farmers for requite technical skills or farmers do not have easy access to milk selling points. Therefore, it is necessary to invest in rural infrastructure to develop farm to market linkages.

Based on these observations, this study advocates for the provision of extended extension services and quality training programmes for dairy farmers to ensure proper farm management. We would also suggest that farmers should be provided with improved cross-bred cattle and buffalo breeds. It is quite necessary to void indiscriminate cross-breeding by educating farmers about modern breeding practices. To enhance the efficiency and profitability of the farm-farmers, it is necessary to expand milk supply networks to remote areas.

Chapter 3

Performance of Pakistan's dairy under integrated cropping systems: An output distance function approach

This study examines the economic performance of dairy-crop farmers in Pakistan. It employs a translog output distance approach to measure the elasticities of input substitution, complementary effects, and technical inefficiency of farmers by using cross-sectional data on 323 farmers. Significant complementary effects are found between labour and land, and labour and irrigation. The overall technical efficiency of the dairy-crop farmers is estimated to be 79 percent; this implies that by eliminating technical inefficiencies, output can be increased by 21 percent. The efficiency differences are explained by factors such as extension services, credit, age, experience, and rented land. The provision of target oriented extension programmes and easy access to credit and regulation of rental markets would be effective in reducing technical inefficiencies.

3.1 Introduction

Agriculture is a mainstay of Pakistan's economy. Its share in the country's Gross Domestic Product (GDP) is 20.9 percent and it provides job opportunities to 43.5 percent of the labour force, while 60 percent of the rural population is dependent on the agriculture sector. The share of agriculture and agriculture-based processed products makes up 70 percent of Pakistan's total exports (Government of Pakistan, 2015). Despite its structural drawbacks, Pakistan's agricultural profile is quite impressive. Pakistan is the world's second largest producer of indigenous buffalo meat, buffalo milk, and oilseed. It is the third largest producer of cottonseed and chillies; fourth for cotton lint and fresh milk; fifth for production of chick peas; sixth for wheat, sugarcane, and dates; thirteenth for the production of rice, and fifteenth for lentils (ITC, 2013).

Agriculture in Pakistan is a combined activity of dairying and cropping production. In cropping, wheat, cotton, rice, sugarcane, and maize are the major crops, accounting for 25.6 percent of the value added in overall agriculture and 5.3 percent in the GDP. Other crops make up a share of 11.1 percent in the value added for the whole agriculture sector, and 2.3 percent for the GDP. Livestock contributes 56.3 percent to the valued added for overall agriculture and 11.76 percent to the GDP. In the livestock sector, the value of milk alone exceeds the combined value of all major crops. However, the area under cultivation for all crops makes up 23.5 million hectares, while the area used only for fodder crops amounts to 2.53 million hectares (Government of Pakistan, 2015).

As dairying and cropping are inter-dependent in Pakistan, crop residues are used as fodder for cattle while manure is used as fertiliser for crops. This may lead to a reduction in costs for small scale farming. Paul & Nehring (2005) have documented that economic performance of diversified farms is positively influenced by output jointness. It suggests that diversification results in cost minimisation in multi-output multi-input production systems, leading to economies of scope (Baumol, Panzar, & Willig, 1982). Coelli & Fleming (2004) argue that significant technical efficiency improvements are made by diversification. Hardaker & Fleming (1994) observe that productivity increases by diversification of cropping practices. Numerous other empirical studies substantiate economies of scope in diversified farming which include Chavas & Aliber (1993), Paul & Nehring (2005) and Rahman (2010). Coelli & Fleming (2004) suggest that modern management practices, improved technology, and husbandry methods are essential for the development of smallholder farming systems. Several studies suggest that management expertise and technological advances support specialisation, while income uncertainty tends to favour diversification owing to input and output price variability (Chavas & Falco, 2012; Mafoua-Koukebene, Hornbaker, & Sherrick, 2016). Several studies have measured the performance of the multi-output dairy sector (Brümmer, Glauben, & Thijssen, 2002a; López, Bravo-Ureta, Arzubi, & Schilder, 2006; Newman & Matthews, 2006).

The objective of this study is to estimate the output elasticities in relation to inputs, and the potential for input substitution. We examine the performance of dairy-crop mixed farming systems in Pakistan and explore the diversification and specialisation efficiency of mixed farms and the factors that influence their technical efficiency. To the best of our knowledge, this is the first study that analyses the efficiencies of dairy-crop mixed farms in Pakistan using an output distance function approach. It will help policy makers formulate policies for the mixed farming system in Pakistan.

The structure of the paper is as follows. Section 3.2 briefly reviews the dairy and cropping system in Pakistan. Section 3.3 specifies the theoretical model and empirical framework. Section 3.4 presents the data and statistical descriptions. Section 3.5 describes the hypothesis tests, empirical model estimation, and results and discussion. Conclusions and recommendations are given in section 3.6.

3.2 Review of agriculture sector in Pakistan

Agriculture in Pakistan is a combined activity of dairying and cropping production. Livestock contributes 56.3 percent to the valued added in overall agriculture and 11.76 percent to the national GDP, while crops account for 36.7 percent of the value added in overall agriculture and 7.6 percent of the GDP. The agriculture sector grew at a rate of 3.85 percent between 1949 and 2015, with 4.31 percent growth in the livestock sector and 3.12 percent growth in the cropping sector (Figure 3).

In Pakistan, 62 percent of the population (115 million) lives in rural areas. Pakistan's rural sector still faces major hurdles for development; in addition to suffering from widespread poverty, the sector faces severe challenges in social, economic, and technological progress. The social problems mainly emerge from a skewed distribution of land ownership which makes the society both rigid and iniquitous. The technological problems stem from traditional methods of cultivation, small landholding, and tenancy farming, all of which restrict incentives for technological progress. The economic problems emerge from the agriculture sector's inability to provide jobs to a growing population and the failure of agricultural markets resulting in lower returns on agriculture (Ahmed & Amjad, 1984).

After independence in 1947, agricultural production remained stagnant for a decade. From 1951 to 1960 the growth rate remained at 1.4 percent with a 2.20 percent growth in the livestock sub-sector and 0.75 percent growth in the cropping sector, the lowest in any decade. In its second five year plan (1955-60), the government planned to purchase milk from specialised dairy farmers and vendors and sell it to consumers after pasteurisation. It also suggested making cooperatives of vendors to transport milk to cities. However, these schemes failed to succeed. To tackle serious water shortages in the agriculture sector, a number of irrigation projects were also constructed. However, the agriculture sector failed to grow due to a lack of integrated policy. By the end of the fifties, food shortages and a lack of raw material for industrial developments pushed policy makers towards an integrated agricultural policy to gain self-sufficiency in food and for exports, reducing unemployment and demand for raw materials for industry.

With the introduction of a second five year plan (1960-65), a new agricultural policy resulted in the advent of the "green revolution". The growth was marked by technological developments and the introduction of high yielding crop varieties, fertilisers, pesticides, mechanisation, and the expansion of irrigation networks by the construction of canals and the installation of tubewells by farmers. The agriculture sector experienced an overall growth rate of 4.72 percent, with 1.61 percent growth in livestock and 5.94 percent growth in the cropping sector.

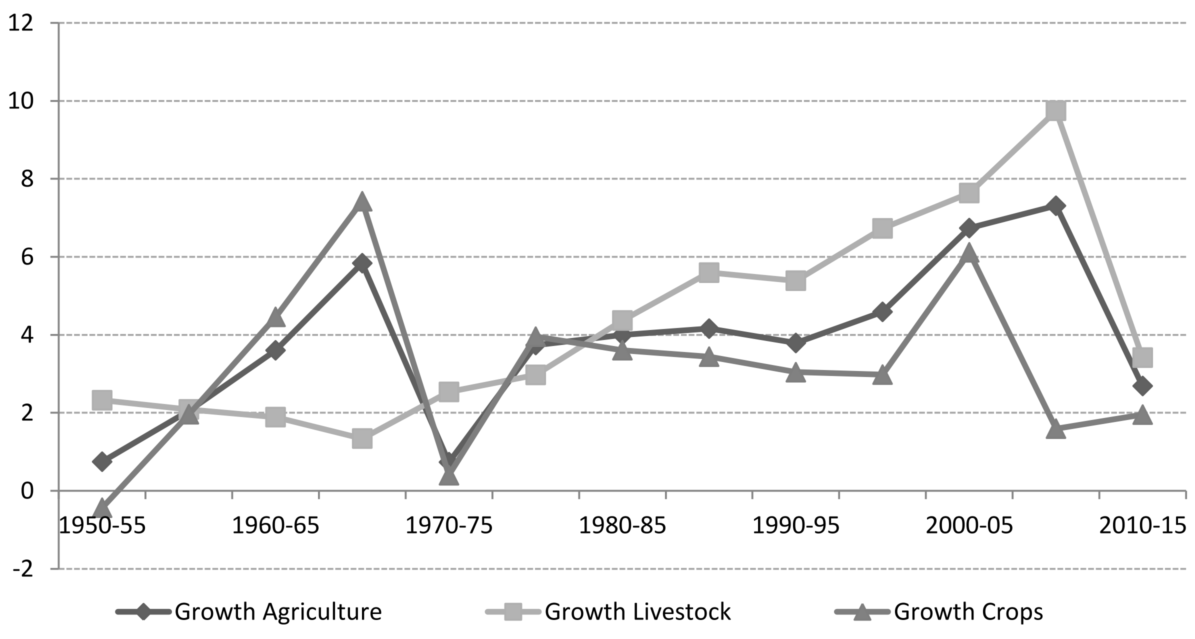
Agricultural growth dropped in the 1970s due to political instability and failures in implementing agricultural policies; extension services, training, research, and education were all neglected. The uncertainty due to selective implementation of land reforms also affected agricultural growth. The agricultural sector experienced 2.23 percent growth with the livestock sector at 2.75 percent and the cropping sector featuring 2.17 percent growth.

In the 1980s, the growth rate of the agriculture sector rose to 4.07 percent with 4.98 percent growth in livestock and 3.52 percent growth in the cropping sector. The agriculture sector recovered mainly due to the introduction of new varieties of cotton seed. Moreover, the government offered incentives to private milk supply channels and encouraged investment in the milk processing industry. This resulted in the installation of 23 milk processing plants in the country.

In the following decade, growth in the agriculture sector remained at 4.19 percent due to extreme floods and severe damage to the cotton crop due to an attack from viral diseases. Moreover, political instability in the country also added to failure in the implementation of policies. The livestock sector grew at 6.05 percent while the cropping sector grew at a rate of 3.22 percent.

After 2000, growth in the agriculture sector accelerated due to increased extension services and enhanced credit facilities which resulted in the mechanisation of the sector. Moreover, new seed varieties also enhanced agricultural productivity. In the dairy sector, the government encouraged investment in the milk processing industry and many new players entered the market. From 2000 to 2015, the growth rate of agriculture rose to 5.57 percent with 6.96 percent growth in the livestock sector and 3.22 percent growth in the cropping sector (Figure 3.1).

Figure 3.1 Growth of agriculture, cropping and livestock in Pakistan



Data source: (Economic survey of Pakistan, 1980; 1988; 1999; 2002; 2015)

3.3 Methodology

Agriculture in Pakistan is characterised by the joint production of cropping and dairy farming. Resource jointness in Pakistan's agricultural sector occurs due to several reasons. In particular, the cultivation of crops and dairying plays a multipurpose role through the efficient use of labour, land, and equipment. By-products of crops are used as fodder for livestock while manure from livestock maintains soil fertility and reduces fertiliser expenses for farmers. Mixed farming also reduces income uncertainty. Moreover, in the case of Pakistan where milk quality is a big issue, rearing cattle at farms also provides fresh milk for farmers.

To better understand the overall performance of multi-output production farms, we adopt a multi-output multi-input distance function approach. If a single output production function was used instead, a number of restrictive assumptions would be imposed (separability of inputs and outputs), potentially leading to biased estimates of performance (Brümmer et al., 2002). Aggregating all outputs assumes that they are all equally important in the production process.

3.3.1 Conceptual framework

The production frontier for multi-output, multi-input technology introduced by Shepherd (1970) can be interpreted as output or input distance functions. The output distance function seeks the potential proportional expansion of outputs and treats the inputs as detailed by Grosskopf, Margaritis, & Valdmanis (1995). It can be defined as: $D_o(x, y) = \min\{\theta : y/\theta \in P(x)\}$. Hence, x represents the vector of inputs, and y denotes the vector of outputs, while θ is the corresponding level of efficiency. $P(x)$ denotes the set of all feasible output vectors ($y \in R^{M+}$) which can be produced by using the input vector ($x \in R^{K+}$), such that: $P(x) = \{y \in R^{M+} : x \text{ can produce } y\}$.

An output distance function $D_o(x, y)$ as noted by Lovell, Travers, Richardson, & Lisa Wood (1994), is non-decreasing, positively linearly homogenous, convex in y, and decreasing in x. If the output vector y belongs to the feasible production set $P(x)$, the output distance $D_o(x, y)$ takes a value less than or equal to one: $D_o(x, y) \leq 1$ if $x \in P(x)$. If y is located on the outer boundary of the output possibility set, the distance function will take a value of unity: $D_o(x, y) = 1$ if $y \in$ iso-quant $P(x) = [y: D_o(x, y) = 1\}$ (Kumbhakar & Lovell, 2000).

We have specified the translog output distance function in this study. The translog functional form is flexible, easy to calculate and allows the imposition of homogeneity conditions

(Coelli & Perelman, 2000). Coelli & Perelman (2000) have specified the translog output distance function for M outputs and K inputs as:

$$lnD_{oi}(x,y) = a_o + \sum_{m=1}^{M} a_m lny_{mi} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} a_{mn} lny_{mi} lny_{ni} + \sum_{k=1}^{K} \beta_k lnx_{ki} + \frac{1}{2}\sum_{k=1}^{K}\sum_{i=1}^{K} \beta_{kl} lnx_{ki} lnx_{li} + \sum_{k=1}^{K}\sum_{m=1}^{M} \delta_{km} lnx_{ki} lny_{mi}, \quad i = 1,2,\dots,N \tag{2.1}$$

Where, i represents the i_{th} farmer in the sample and N is the sample size.

In order to achieve the production frontier surface, we set $D_o(x, y) = 1$, which states that the left hand side of Equation 2.1 is equal to zero. The restrictions required for linear homogeneity of degree one in the outputs are:

$\sum_{m=1}^{W} a_m = 1, m = 1, 2, \dots, M$

and

$\sum_{n=1}^{M} a_{mn} = 0, m = 1, 2, \dots, M$

and

$\sum_{m=1}^{M} \delta_{km} = 0, k = 1, 2, \dots, K$

Restrictions required for symmetry are:

$a_{mn} = a_{nm}, m, n = 1, 2, \dots, M$

$\beta_{kl} = \beta_{lk}, k, l = 1, 2, \dots, K$

For imposing homogeneity of degree one on the outputs, we have to normalise the output distance function by arbitrarily selecting one output (Lovell et al., 1994). This implies that by taking the M_{th} output and setting $\vartheta = 1/y_M$, we obtain

$D_o(x, y / y_M) = D_o(x, y) / y_M$

We then obtain the following translog output distance function:

$$\ln(D_{oi}(x,y)/y_{Mi}) = a_o + \sum_{m=1}^{M-1} \alpha_m lny^*_{mi} + \frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1} a_{mn} lny^*_{mi} lny^*_{ni} + \sum_{k=1}^{K} \beta_k lnx_{ki} + \frac{1}{2}\sum_{k=1}^{K}\sum_{i=1}^{K} \beta_{kl} lnx_{ki} lnx_{li} + \sum_{k=1}^{K}\sum_{m=1}^{M-1} \delta_{km} lnx_{ki} lny^*_{mi} \tag{2.2}$$

Where $y^*_{mi} = y_{mi} / y_{Mi}$, and $y_{mi} \neq y_{Mi}$. This equation can be written more succinctly as:

$\ln(D_{oi}(x,y)/y_{Mi}) = TL(x_{ki}, y_{mi}/y_{Mi}, \alpha, \beta, \delta)$

Thus, we can write

$-\ln(y_{Mi}) = TL(x_{ki}, y_{mi}/y_{Mi}, \alpha, \beta, \delta) - \ln(D_{oi}(x,y))$

Where $-\ln(D_{oi}(x,y))$ represents the distance function from the boundary. Finally, ting $\ln(D_{oi}(x,y)) = u_i$, and appending an error term to the right-hand side, the translog output distance function becomes:

$-\ln(y_{Mi}) = TL(x_{ki}, y_{mi}/y_{Mi}, \alpha, \beta, \delta) + v_i - u_i$

When the function estimates the stochastic errors, it transforms into a stochastic production frontier perspective developed by Aigner, Lovell, & Schmidt (1977) for production functions. So, v_i is a two-sided random disturbance which is assumed to be independent and identically distributed *i.i.d.* $N(0, \sigma_v^2)$. The u_i is negative random term which captures the inefficiency and represe

nts the distance to the boundary and is independently distributed $N(\mu_i, \sigma_u^2)$, truncated above zero of the normal distribution (Battese & Coelli, 1988; Battese et al., 1996; Battesse & Coelli, 1995).

3.3.2 Empirical specification

We estimate a translog output distance function with two outputs and six input variables. The output variables are defined as the total revenue from milk and crop production respectively. The input variables of seed, irrigation, fertilisers, and veterinary are values of expenses for the respective inputs. The labour is the number of people working on the farm and land is the total land area in acres. The resulting translog distance function is defined as:

$$-\ln(y_{1i}) = a_o + a_1 \ln(y_{2i}/y_{1i}) + \frac{1}{2} a_{11} \ln(y_{2i}/y_{1i}) \ln(y_{2i}/y_{1i}) + \sum_{k=1}^{6} \beta_k lnx_{ki} + \frac{1}{2} \sum_{k=1}^{6} \sum_{i=1}^{6} \beta_{kl} lnx_{ki} lnx_{li} + \sum_{k=1}^{6} \delta_{k1} lnx_{ki} \ln(y_{2i}/y_{1i}) + v_i - u_i \quad (2.3)$$

We estimate the "one-step" model using the maximum likelihood method which specifies both the stochastic frontier and technical inefficiency models. According to Battese & Coelli (1995) the technical inefficiency model is describes as:

$$\mu_i = \delta_o + \sum_{h=1}^{9} \delta_h z_{hi}$$

Where z_i represents the variables related to farm characteristics that affect the technical inefficiency. These variables are explained in detail in the following section.

3.4 Data and descriptive statistics

This study was conducted in Pakistan's Punjab province. The word Punjab literally means "land of five rivers." Punjab is Pakistan's largest province in terms of population (56 percent) and share in national GDP (59 percent). The agriculture sector contributes 28 percent to the output of Punjab and provides employment to roughly 40 percent of the province's work force. Punjab has around 29 percent of the total reported area of Pakistan, 57 percent of the total cultivated land, and 69 percent of the total cropped area. Livestock is an important subsector of agriculture and Punjab has 56 percent of the total national herd, including 65 percent of the total buffalo population and 49 percent of the total cattle share. The province also accounts for almost 65 percent of the total milk produced in Pakistan. It contributes a major share to the country's cropping sector by providing around 83 percent of all cotton, 80 percent of wheat, 97 percent fine aromatic rice (Basmati), 63 percent of sugarcane, and 51 percent of corn to national food production. Among fruits, Punjab's share in mango production accounts for 66 percent, while the citrus share is more than 95 percent, guava 82 percent, and dates accounts for 34 percent of the total national production (GOP, 2012).

Punjab has an extensive network of canals, as well as tube-wells owned by farmers, that irrigate 12.51 million hectares of land in the province. This provides an environment conducive to livestock and cropping in the region. Considering the importance of the area, we collected data from two regions of Punjab province, South Punjab and North or Upper Punjab, in February-April 2013. These regions are based on cultural divisions of the province. Data were collected through the random selection of farmers from twelve districts of the two regions; six districts from each region. To collect the data, a well-structured questionnaire was prepared and information was collected on various factors including the socioeconomic characteristics of farmers, milk and crop outputs and inputs, prices and milk marketing strategies of the farmers. As an initial step in data collection, we conducted a pilot test to corroborate the suitability of the questionnaire in the field. We revised the questionnaire to take into account the errors detected through the pilot survey. We collected data from 345 farmers in Punjab who are primarily dairy farmers and also cultivate crops. Due to the fact that some farmers have no crops and the output distance function does not consider zero values in outputs, we are left with information on 323 farms. Table 3.1 summarises the variables of the output distance function and table 2 summarises the variables of the technical efficiency model.

We estimate the translog distance function with two outputs and six inputs. The output variables are defined as the total revenue from milk production and crops respectively. The input variables include seed, irrigation, fertilisers, dairy expenses, labour, and land. Seed and irrigation are the values of expenses for the respective practices. We have aggregated the values of expenses relating to fertilisers, pesticides, and manures into a single variable called fertilisers. The dairy expenses variable represents the aggregated value of expenses relating to veterinary services and concentrates. Labour is defined as the number of people working on a farm, including family and hired labour. Land is the total area of land used for dairying and cropping activities, measured in acres. It includes family owned land and also rented-in land.

Table 3.1 Summary of variables in the output distance function

Variables	Unit	Mean	Std.Dev.	Min	Max
Milk (y_1)	Rupees	608877	459832	82035	3493050
Crops (y_2)	Rupees	1969585	2857888	34125	19905000
Seed (x_1)	Rupees	98864	178527	2754	1539200
Irrigation (x_2)	Rupees	185107	304964	3950	3100025
Fertilisers (x_3)	Rupees	392079	570766	17930	3516300
Labour(x_4)	People	3.49	1.60	1	10
Dairy inputs (x_5)	Rupees	91822	117991	2280	1345000
Land (x_6)	Acres	21.13	25.86	1	175

Table 3.2 describes the variables of farm specific characteristics that may affect the technical efficiency model. Experience is an important variable in defining the technical efficiency of farmers. Farmers enhance and accumulate their experiences over the time by learning and adopting new technologies, market behaviours, and understanding economic and social environments to make better choices. It may increase their productive efficiencies through adopting cost-effective measures and to cope with adverse shocks. Age is expected to have either negative or positive effect on the efficiency of farmers. Experience and age variables are both measured in units of years.

Extension services create awareness among farmers of new technology and modern farms practices. Farmers get information on new improved crop varieties and breeds of cattle. Generally, extension services are considered to have positive effect on the technical efficiency of farmers. However, quality and focus of extension services defines the outcome of such programmes. Lopez (1996) argued that extension programmes in Chilian agriculture increased the production through greater use of inputs rather than better use of inputs to enhance productivity. Extension visits and extension visits of neighbours represent the number of visits paid. Extension visits of neighbours are used to capture the spillover effects of extension services. These are an aggregate of visits paid to the three closest neighbours. We obtained the three closest neighbouring farms for a given individual farm through GPS data.

Theoretically, rented land is expected to increase the allocative efficiency of farmers by efficient use of labour and other farm inputs. It may also leads to appropriate farm size. Developed land rental markets results in transfer of land from less efficient to more efficient farmers (Deininger & Feder, 2001; Deininger, Zegarra, & Lavadenz, 2003; Faruqee & Carey, 1997). However, rented land is subjected to tenure insecurity, which may discourage long-term investment and reduce agricultural productivity. In Pakistan land ownership is extremely skewed with majority of the farmers (61 percent) have less than two hectares of land. Many small farmers rent land to expand their agricultural operations and efficient use of family labour. To capture the effect of rented land we use its dummy, where rented-in land = 1 and 0 otherwise.

Credit is fundamental component of all production processes (Dicken, 2011). Credit constraints not only affect the farmers' purchasing power in the short run but also affect the long-term investment and technology adoption. These causes, in turn, influence the technical efficiency of farmers. Theoretically, credit can have both positive and negative effects on the technical efficiency of farmers. To capture the effect of credit we used its dummy, where access to institutional credit = 1 and 0 otherwise. To represent regional effects, we use the dummy of region, where North = 1 and 0 otherwise.

In a multi-output production system, crop diversification leads to cost reduction (Baumol et al., 1982) by using outputs of one system as inputs in other system. It also leads to efficient use of labour and other resources. In Pakistan where dairying and cropping are combined activity, residues of sugarcane, wheat, rice and cottonseed cake are used as feed for cattle while manure is used as fertilisers for crops. It is expected that more diversified farms have positive effect on the efficiency of farmers. The crop diversification index (CDI) is used to capture the effect of diversification on technical efficiency. The Herfindahl index (HI) can be calculated as:

$$HI = \sum_{i=1}^{n} p_i^2$$

Where p_i is the share of each crop which can be defined as:

$$p_i = \frac{A_i}{\sum_{i=1}^{n} A_i}$$

$$cdi = 1 - \sum_{i=1}^{n} p_i^2 = 1 - HI$$

Here, A_i is the area under each crop and $\sum_{i=1}^{n} A_i$ is the total cropped area. The value of index is bounded between 0 and 1. Here the value of 1 means fully diversified and 0 means fully specialised.

Table 3.2 Summary of variables in the technical inefficiency model

Variables	Unit	Mean	Std.Dev.	Min	Max
Age	Years	45.34	10.95	21	75
Experience	Years	16.60	8.77	2	45
Rented land	Dummy	0.33	0.47	0	1
Region	Dummy	0.51	0.50	0	1
Credit	Dummy	0.20	0.40	0	1
Extension visits	Numbers	13.59	8.51	1	61
Neighbours' Extension visits	Numbers	40.93	16.28	8	123
Crop diversification index	Percentage	0.54	0.09	0	0.74

3.5 Results and discussions

3.5.1 Hypothesis results

In order to proceed with estimations for this study, we seek to test three hypotheses of model specification and variable selection through a likelihood ratio test. Table 3.3 describes the results of the hypotheses tested. The first hypothesis defines the selection of the correct functional form; the log likelihood test rejects the Cobb-Douglas specification in favour of a translog production function. The second hypothesis specifies that inefficiency effects are absent from the model at every level; the likelihood ratio test rejects the null hypothesis. This indicates that significant technical inefficiencies exist in Pakistan's dairy sector. The final hypothesis states that farm-specific factors do not influence the inefficiencies; the likelihood ratio test rejects the null hypothesis, indicating that farm-specific factors affect the inefficiency model.

Table 3.3 Hypotheses tests for model specification and statistical assumptions

Null hypothesis	$L(H_0)$	$L(H_1)$	d.f.	$\lambda^2_{0.05}$	Decision
1. $H_0 : \beta_{ij} = 0$	12.29	52.71	22	93.64	Rejected
Testing the specification of the technical inefficiency mode					
2. $H_0 : \gamma = \delta_0 = \delta_1 = \cdots = \delta_n = 0$	51.27	52.71	1	2.84*	Rejected
3. $H_0 : \delta_1 = \delta_2 = \cdots = \delta_7 = 0$	51.29	85.06	10	65.53***	Rejected

*Critical values are taken from (Kodde & Palm, 1986). For this value, the statistic λ has a mixed χ^2 distribution.

3.5.2 Estimates of stochastic distance function

We have normalised the outputs and inputs by their respective means to facilitate interpretation. Hence, the first-order estimates of the translog distance frontier can be described as partial production elasticities at the sample mean (Brümmer, Glauben, & Thijssen, 2002). Milk revenue is chosen as the dependent variable and for normalizing the crops output. In the final estimation, we have dropped the cross-terms between output and inputs using the likelihood ratio test. The maximum likelihood estimates of the distance function are summarised in Table 3.4 and described below.

The share of milk in total revenues is calculated to be 24 percent, while the share of crops is 76 percent. These results are both expected due to the fact that dairying in Pakistan is practiced on a small scale and farmers allocate more land and resources to cropping in comparison to dairy farming. The positive and significant value of the square terms of crops confirms evidence of the convexity curvature property of other crops at the sample mean[3]. Brummer et al.

[3] The nlWaldtest has rejected the violation of the curvature property of the output distance function at 1 percent.

(2002) describe that in order to conform to the monotonicity property at sample means, the distance elasticities for a "well-behaved" input must be negative.

Table 3.4 Estimates of translog output distance function

Variables	Parameters	Coefficients	Standard Error
Constant	α_0	-0.237*	0.126
$\ln(y_2/y_1)$	α_1	0.753***	0.029
$\ln(x_1)$	β_1	-0.166***	0.031
$\ln(x_2)$	β_2	-0.079**	0.037
$\ln(x_3)$	β_3	-0.448***	0.057
$\ln(x_4)$	β_4	-0.023	0.054
$\ln(x_5)$	β_5	-0.091***	0.021
$\ln(x_6)$	β_6	-0.138*	0.080
$0.5\ln(y_2/y_1)^2$	α_{11}	0.067***	0.021
$0.5\ln(x_1)^2$	β_{11}	-0.190**	0.077
$0.5\ln(x_2)^2$	β_{22}	0.004	0.047
$0.5\ln(x_3)^2$	β_{33}	-0.175	0.147
$0.5\ln(x_4)^2$	β_{44}	0.311**	0.139
$0.5\ln(x_5)^2$	β_{55}	-0.024	0.019
$0.5\ln(x_6)^2$	β_{66}	-0.106	0.306
$\ln(x_1)\ln(x_2)$	β_{12}	0.049	0.047
$\ln(x_1)\ln(x_3)$	β_{13}	-0.056	0.055
$\ln(x_1)\ln(x_4)$	β_{14}	-0.003	0.061
$\ln(x_1)\ln(x_5)$	β_{15}	0.014	0.022
$\ln(x_1)\ln(x_6)$	β_{16}	0.202*	0.109
$\ln(x_2)\ln(x_3)$	β_{23}	0.027	0.04
$\ln(x_2)\ln(x_4)$	β_{24}	0.114*	0.069
$\ln(x_2)\ln(x_5)$	β_{25}	-0.028	0.024
$\ln(x_2)\ln(x_6)$	β_{26}	-0.067	0.102
$\ln(x_3)\ln(x_4)$	β_{34}	0.066	0.094
$\ln(x_3)\ln(x_5)$	β_{35}	0.021	0.033
$\ln(x_3)\ln(x_6)$	β_{36}	0.138	0.178
$\ln(x_4)\ln(x_5)$	β_{45}	-0.027	0.036
$\ln(x_4)\ln(x_6)$	β_{46}	-0.328**	0.146
$\ln(x_5)\ln(x_6)$	β_{56}	-0.024	0.057
Sigma_v		0.165	
Sigma_u		0.090	
$Sigma^2$		0.035	
Lambda		0.547	
Log likelihood		85.065	

* p<0.10, ** p<0.05, *** p<0.01

The results show that the input elasticities of seed, irrigation, fertilisers, dairy, and land are all negative and statistically different from zero. However, labour is not statistically significant but has the right sign. The absolute value of distance elasticities of fertilisers (0.448) and seed (0.166) show a higher share of these inputs when compared to other input variables in the distance function. This might indicate that farmers use fertilisers and quality seed to increase output.

In cross terms, we have found significant evidence of a substitution effect between labour and land. This indicates that with an increase in landholdings, farmers use less labour and shift towards mechanisation. Complementary effects are observed between irrigation and labour which might indicate that due to the conventional system of irrigation, more labour is required to perform the operation. Farmers who grow water-intensive crops like sugarcane and rice are also expected to have greater labour requirements. Another possibility may arise from higher land fragmentation that leads to higher labour requirements for irrigation. Seed and land variables also show complementary effects which may indicate that with increase in landholdings, farmers are more inclined to cultivate major crops which require more seed.

The negative sum of the input elasticities or simple sum of the absolute input elasticities can be described as the scale elasticity (Färe & Primont, 1995). This measures the proportional increase in all outputs caused by an increase of the same proportion in all inputs. The absolute sum of input elasticities is estimated to be 0.94, indicating slightly decreasing returns to scale at the sample mean.

3.5.3 Estimates of technical efficiency

The results of the technical inefficiency effect are presented in Table 3.5. The study observes that the dummy of region is negative and significant, highlighting that farmers in the northern region of Punjab are more efficient in comparison with South Punjab. The age of the head of the household has a positive and significant effect on the technical inefficiency of farmers. This indicates that younger farmers tend to be technically more efficient than older ones, implying that they are more willing to improve their farming knowledge through modern techniques (Coelli & Battese, 1996). It may also indicate that agriculture sector in Pakistan in labour intensive and older farmers are less energetic to do the tough operations. Experience has a negative and statistically significant effect on the technical inefficiency of farmers.

Access to credit has a negative and statistically significant effect, indicating that access to credit increases efficiency. In Pakistan, farmers face a serious shortage of cash in the summer season due to high requirements of both water and fertilisers which consequently affects efficiency. These results show that access to credit gives farmers the opportunity to buy fertilisers and other farm inputs at the best time, and may also lead to technological progress through the mechanisation of farm activities. Binam, Tony, Wandji, Nyambi, & Akoa (2004) argue that credit facilities enhance farmers' ability to adopt new farm technology which in turn increases their productivity.

Table 3.5 Estimates of technical efficiency model

Variables	Parameters	Coefficients	Standard Error
Constant	α_0	0.512***	0.169
Age	α_1	0.004***	0.001
Experience	α_2	-0.006***	0.002
Rented Land	α_3	-0.056*	0.030
Region	α_4	-0.172***	0.040
Credit	α_5	-0.063*	0.032
Extension visits	α_6	-0.003*	0.001
Crop diversification index	α_7	-0.133	0.159
Extension visits of neighbours	α_8	-0.003***	0.001

* p<0.10, ** p<0.05, *** p<0.01

Rented-in land has a negative and statistically significant effect on technical inefficiencies of farmers, indicating that farmers who have rented land are technically more efficient. This implies that farmers who rent land are more specialised in farming and rented land also leads to appropriate farm size. This in turn increases farmers' efficiency of labour and inputs use.

Extension services to farmers have a statistically negative effect on technical inefficiencies. This implies that extension services improve the technical efficiency of farmers through imparting knowledge on modern farming practices, farm management, and technical skills, which increases their technical efficiency, thereby ensuring enhanced efficiency in the long-term. Visits paid to neighbouring farms have a negative and statistically significant effect on technical inefficiencies. This implies that significant spillovers of knowledge occur when farmers exchange their information which in turn increases their technical efficiency.

The variable for crop diversification has a negative sign but is not statistically significant, suggesting that crop diversity does not substantially reduce technical inefficiency. Crop diversity in the setting of Pakistan's agriculture sector reduces the risk of crop failure. Furthermore, residues from several crops are used as fodder for dairy, including sugarcane leaves and wheat straw. However, farmers are often unable to select the best combination of crops. Coelli & Fleming (2004) argued that diversification of farm activities enhances efficiency through providing the opportunity to select several farming activities which complement the different inputs from various resources.

3.5.4 Technical efficiency

We have estimated the technical efficiency for each household in the model. The average estimated technical efficiency indicates that milk producers produce 79 percent of the potential output at their current state of technology. This implies that, on average, 21 percent of milk production can be increased by adopting the improved practices.

The distribution of efficiency scores ranges from a minimum of 0.56 to a maximum of 0.95. Figure 3.2 shows that approximately 47 percent of households have a technical efficiency score greater than 0.80, whereas 34 percent of households have technical efficiency scores greater than 0.70 and less than or equal to 0.80, and 19 percent of households have technical efficiency scores less than or equal to 0.70.

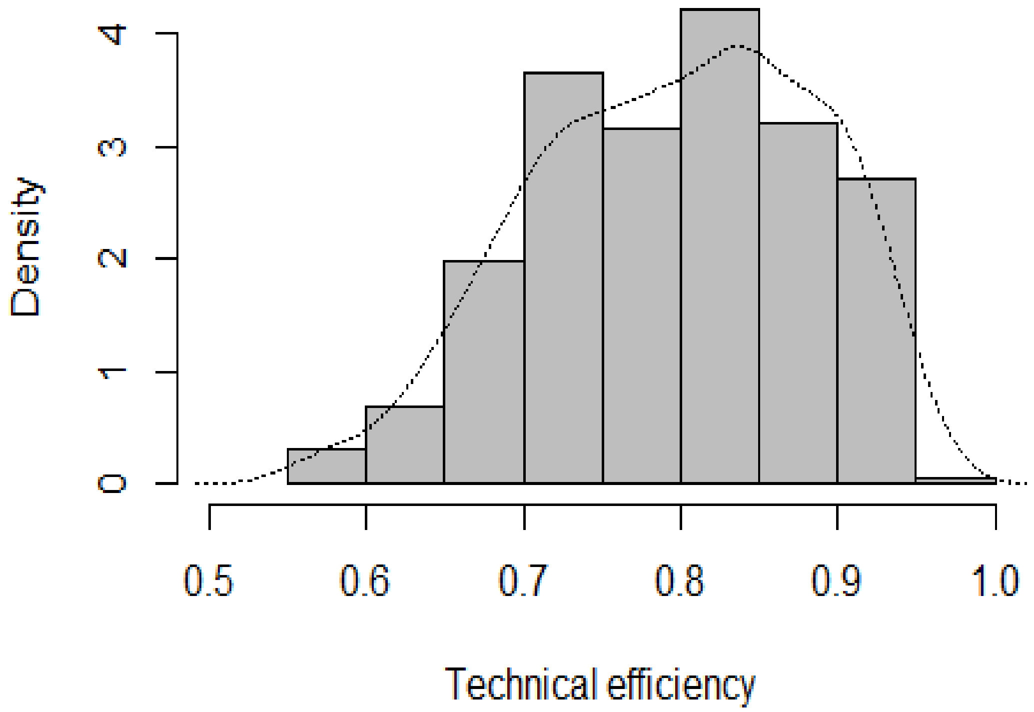


Figure 3.2 Distribution of technical efficiencies

3.6 Conclusions and recommendations

In this study we analyse the production performance of dairy-crops farmers in Punjab, Pakistan using cross-sectional data of 323 randomly sampled farms. We employ the stochastic output distance function approach to estimate input substitution and complementary effects, and identify the determinants of technical inefficiency of dairy farmers to potentially help policy makers to introduce more effective target-oriented policies.

The empirical results show that the marginal rate of transformation (MRT) between milk and crops is negative and significantly different from zero. Furthermore, the results of first order partial elasticities of all inputs reveal that the milk output increases monotonicitly. However, we have found evidence of decreasing returns to scale (RTS = 0.94). The cross-term effects of inputs point to significant substitutions effects between inputs, including; labour and land, and complementary effects between irrigation and labour, and between seed and land. The negative complementary effect between labour and land suggests that with an increase in landhold-landholdings, farmers shift towards mechanisation. Meanwhile, the positive complementary effect between labour and irrigation indicates that farmers with traditional systems of irrigation require more labour.

The empirical results of the technical inefficiency model show that the average estimated technical efficiency of dairy-crop farmers is 79 percent; this implies that there are opportunities to expand production by 21 percent without any additional resources, given the current level of production technology.

Rented land positively affects the efficiency of farmers which suggest that it may provide more appropriate farm size along with a more efficient use of labour; this in turn enhances technical efficiency. In Pakistan, renting of agricultural land is not regulated and farmers have no security in case of renting in or renting out land. Development of land rental markets can be an important policy instrument to increase agricultural production to enhance technical efficiency of farmers.

The results of study show that extension services enhance farmers' technical efficiency by imparting technical skills and advanced farm management practices, thereby ensuring enhanced efficiency in the long-term. However, although crop diversification decreases the technical inefficiencies of farmers, it does not have a statistically significant effect.

This study suggests that policy makers should focus on launching programmes to enhance both technical and management skills of farmers, and to connect them with new innovations in dairying and cropping through extensive extension service programmes. It is very important that farmers should be educated about efficient use of farm inputs to reduce cost and cope with increasing environmental challenges. Extension services can also play an important role in selection of crops to improve crop rotation and crop diversification practices to ensure food security and can also create awareness among farmers about modern farm technologies to enhance productivity and efficiency.

An important policy concern in Pakistan is to increase the farm productivity and efficiency through mechanisation and modernisation of farm practices. Pakistan's per hectare use of horsepower is 1.50 which is lower than its neighbouring countries India (2.50HP) and China

(3.88HP). Farm mechanisation will not only reduce cost of production and save time but can also bring more land under cultivation. Moreover, we have observed in this study that traditional irrigation practices require more use of labour. Agricultural credit is an important tool not only to increase purchasing power of farmers in the short-run to meet inputs requirements but it can also enhance farm mechanisation and modernisation of agricultural practices. Thereby ensuring easy access of credit is an important policy instrument.

Chapter 4

Choice between traditional and modern milk supply channels by farmers in Punjab, Pakistan: A logit regression approach

Considering the changing milk marketing structure in Pakistan, this study investigates the factors influencing farmers' choice of milk marketing channels in Punjab, Pakistan. The empirical results indicate that the volume of milk sold, improved cattle breeds, milk prices, distance to milk collection unit, and payment methods are all significant factors which influence farmers' choices between two market channels. The quantity of milk sold and improved cattle breeds are both important factors leading to the selection of modern supply channels. However, milk prices, the distance to the milk collection unit, and long payment periods discourage farmers' participation in modern channels. This study suggests that to enhance collection the provision of advanced dairy technology, institutional support, and investment in rural infrastructure to improve access to rural farmers could enhance farmers' capabilities of managing resources and hence shift them towards commercialisation.

4.1 Introduction

Food production and marketing have experienced revolutionary changes all over the world and integrated food supply channels are the fastest growing and most prominent market phenomenon (Delgado, 1999; Lundvall et al., 2009). These changes have forced industry participants to adopt appropriate strategies to meet the demands of new market challenges. In the dairy sector, immense changes have been witnessed in milk marketing, in terms of value addition, product differentiation, and market competition (Bennett, Lhoste, Crook, & Phelan, 2006; Moran, 2009). Modern milk supply channels have been expanding their business in developing countries since the early 1990s, and demand for high-value products is increasing (Balsevich, Berdeguie, & Reardon, 2006; Reardon & Timmer, 2005). Integrated supply channels provide new opportunities to farmers in terms of price and volume stability (Michelson, Reardon, & Perez, 2012). Yet at the same time, they also pose new challenges in the form of food safety standards and continuous milk supply (Balsevich, Berdeguie, Flores, Mainville, & Reardon, 2003; Okello & Swinton, 2007; Sharma, Kumar, & Singh, 2009).

With the expansion of modern milk supply channels there are growing concerns over whether or not small scale farms will be able to reap the benefits from emerging opportunities. Consequently, there has been some apprehension over the impact of modern milk supply channels on small farms in developing countries. These new milk supply channels have introduced considerable changes in milk procurement, processing, and wholesaling. Nevertheless, studies in many developing countries suggest that it is mainly large scale farmers who benefit from these channels while small scale farmers find it difficult to meet the quality and food safety standards. In addition to this, modern supply channels also face high transaction costs from dealing with millions of small farmers (Reardon & Timmer, 2007).

In Pakistan, from the early 2000s, many new players entered into the processing industry and numerous large scale dairy farms were built in the country. This resulted in massive investment in the milk processing industry and introduced advanced marketing strategies. Some milk processing companies implemented modern procurement systems and contract relationships with farmers to supply dairy inputs and purchase good quality milk. In Pakistan, modern integrated milk supply channels are growing at a pace of seven to eight per cent per year. Two of the major players in modern milk supply channels are Nestle and Engro foods, with an almost 34 percent share of each channel (Euromoniter, 2014). This has resulted in the development of a competitive structure of milk supply in Pakistan. However, despite all these changes, the milk marketing structure in Pakistan is largely unorganised and dominated by informal markets. In traditional channels milk is marketed through multi-layered channels. The most important players in traditional market channels are milkmen or vendors, who purchase milk from small dairy holders in rural areas and sell it to customers in urban centres. Vendors sell milk directly to consumers or to small sweet shops, hotels, and restaurants. However, farmers also sell milk directly to consumers in village areas as well as small tea shops and restaurants. Market players in traditional milk markets purchase milk at the farm gate, while in the case of modern milk supply channels, farmers need to travel an average of 1.86 km to sell milk. This takes a lot of time and also increases transportation costs. Vendors also benefit from other advantages, including quick payments and no quality control issues from traditional channels.

Many studies have been conducted to identify the factors influencing the participation of farmers in alternative supply chains. Misra, Carley, & Fletcher (1993) analyse the factors influencing the farmers' choice of milk handlers in the USA and find that the price of milk is the main deciding factor when choosing marketing channels. Abdulai & Birachi (2009) examine the nature of the coordination mechanism and the determinants of fresh milk supply chains in Kenya. The study finds that farmers prefer written contracts; furthermore, both distance to markets and the gender of the operator are primary determinants in the choice of marketing channels. Staal et al. (2006) address the factors influencing the choice of farmers' participation in alternative milk channels in India and find that transaction costs are an important determinant. Several other studies focus on the determinants of participation in alternative milk supply chains, including Kumar, Staal, & Singh (2011), Bardhan, Sharma, & Saxena (2012), Sharma, Kumar, & Singh (2009) and Mburu, Wakhungu, & Gitu (2007).

In Pakistan, very few studies have been conducted to understand the impact of modern milk supply channels on farmers' production. Burki & Khan (2011) and Sadaf & Riaz (2012) studied the impact of modern supply channels on the technical efficiency of farmers, while Zia (2007) analysed the competitiveness of milk marketing channels and the role of government policies, and Qasim et al. (2005) investigated the profitability of different players in traditional milk marketing channels. However, no studies have been conducted in Pakistan to understand the factors affecting farmers' choices of milk marketing channels in this evolving market structure.

The broad motivation of this study is to identify the factors which influence farmers' participation in modern and traditional milk supply channels and to assist in formulating policies and programs to improve the milk supply system in Pakistan.

The structure of the paper is as follows. Section 4.2 reviews the structure of the dairy industry in Pakistan. Section 4.3 presents the data and variables, and section 4.4 contains the methodology and empirical model. Section 4.5 describes the results and discussions, and section 4.6 contains conclusions and recommendations.

4.2 Changing structure of dairy in Pakistan

Dairying is an important segment of Pakistan's economy, accounting for 11.76 percent of the national Gross Domestic Product (GDP) and constituting 56 percent of agricultural value added, while milk alone accounts for 27 percent of the agricultural sector (The Express Tribune, 2014) and 75 percent of the total value of livestock products (Zia, 2007). The livestock sector employs half of the work force and 35 million people earn approximately 30-40 percent of their income from livestock (IFAD, 2013). It also serves as security for farmers against crop failure. Pakistan has an annual production of 40 billion litres of milk, out of which 32 billion litres are available for human consumption (Rana & Mumtaz, 2012). Despite having plentiful milk production, Pakistan cannot fulfil its growing demand for milk and is a net importer of powdered milk and other dairy products.

However, Pakistan presents an interesting picture of its dairy sector in many ways. First, Pakistan is the world's fourth largest producer of milk. Secondly, per capita consumption of milk is higher in Pakistan than any other Asian country (159 kg per person). Third, due to the low level of milk processing and the high demand for milk and milk products in urban areas, several new companies entered into the processing of UHT milk to fill the gap after 2000, including Engro Foods, Shakar Gunj Foods, Noon Dairy Pakistan, Nirala Dairy, Alpha Dairy, Royal Dairy, and numerous others (Khan, 2011).

In most developing countries in South Asia, Sub-Saharan Africa, and Latin America, the share of traditional small scale milk markets is above 80 percent of the total milk marketed (Omore, Staal, & Randolph, 2004). In Pakistan, more than 90 percent of the total milk marketed is still supplied through traditional milk supply channels. Out of the total milk available for human consumption in the country, nearly 40 percent is marketed, while the remaining 60 percent is consumed by rural households (Zia, 2007).

Nevertheless, there are growing concerns about the quality of milk supplied by traditional milk channels, especially adulteration in milk from water and chemicals, and poor milk handling techniques. In addition, urbanisation in Pakistan has been growing at a rate of 3.1 per cent per year (Ghani, 2012). Similarly, the demand for milk in Pakistan has been growing at 15 percent per annum (Bokhari, 2015). In such situations, traditional milk channels are unable to meet the expanding gap between supply and demand. This has created a huge potential for modern market channels to expand their business. Even though both multinational and local milk processing companies are an important component of organised milk markets in Pakistan, milk procurement through these channels is still very low. Furthermore, the distribution of supply channel networks and formal systems in terms of the volume of milk handled, marketing infrastructure, and installed processing facilities, is mostly concentrated in specific districts and provinces. Out of the 21 milk processing plants in the country, 19 are in Punjab and 2 are in Sindh, while the remaining provinces and territories have no milk processing facilities (Khan, 2011).

Consequently, despite being the fourth largest milk producer in the world, Pakistan has not been able to harness the maximum potential of its dairy sector. The government's policies towards the dairy sector have been rather discouraging. In their first five year plan (1955-60), the government developed a proposal to buy milk from specialised dairy farmers and vendors, pasteurise it, and sell it to consumers in sealed bottles. It also suggested making cooperatives of milkmen/vendors for the transportation of milk to cities. These projects came into operation in two major cities, Karachi (1965) and Lahore (1967). However, these schemes remained unsuccessful due to financial losses and a lack of funding from the government. The second (1960–1965) and third (1965–1970) five year plans did not put much emphasis on the development of the dairy sector.

In the 1970s and early 1980s, the government offered incentives to private milk supply channels and encouraged investment with the introduction of aseptic packaging material for ultra-high temperature (UHT) treated milk by Tetra Pak Pakistan Limited. The milk processing industry received massive investment in Pakistan, and the private sector established 23 milk processing plants. Nevertheless, Pakistan was still facing a lack of infrastructure, social taboos for selling milk, and little acceptance of processed milk by consumers. Most of the players could not sustain the higher costs of milk collection and the low levels of milk processing and sales. In the early 2000s, many new players entered into the milk processing industry, with the number increasing from 2 in the 1990s to 21 between 2000 and 2010. This changing scenario has increased the competition in milk supply markets in Pakistan.

Pakistan's supply channel networks underwent considerable improvement after the 1970s, when selling milk was considered to be a social taboo and now country is expecting a "white revolution." However, milk collection in the country is still facing many major challenges, from serious quality problems with collected milk, to a colossal drop in milk production in the summer, and lack of access to proper marketing channels (Rana & Mumtaz, 2012).

4.3 Data and sampling techniques

This study aims to understand the determinants of dairy farmers' participation in both formal and informal milk supply channels in Pakistan. We conducted the study in Punjab province of Pakistan which is country's largest with 56 percent of the total population. It is also the highest milk producing province in the country, with almost a 64 percent share in total milk production. It has the world's most renowned breeds of buffalo (Neeli Ravi) and cattle (Sahiwal). Buffalo is the major milk producing animal in Punjab, taking a 65 percent share of total dairy population and a 64 percent share in total milk production followed by cattle with a 49 percent share of total population and 35 percent share of total milk production (LDDDP, 2013). Besides local cattle breeds, cross bred breeds and imported cattle breeds are also gaining importance in dairy farming. In Punjab, crossbred and imported cattle breeds have a 17 percent share of the total cattle population in Punjab (GOP, 2006)

Punjab province has two regions based on cultural divisions; North Punjab and South Punjab. North Punjab has a 56 percent share in total provincial herd with 66 percent share in buffalo population and 45 percent share in cattle population in the province. In terms of milk processing plants, Punjab has 19 out of the 21 facilities in the country, with 14 in North Punjab and 5 in South Punjab (BSP, 2015).

We collected data through the random sampling of 12 districts in Punjab, with 6 districts from each region, during February-April 2013. We interviewed 345 farmers in total, with 174 farmers from North Punjab and 171 farmers from South Punjab. From each district we randomly selected a Union Council[4] and collected the data from one Mauza[5] of each Union Council. Given the importance of changing milk marketing structure, we focused on two major marketing channels: modern milk supply channels and traditional channels (vendors, didirect sale to consumer, and sweet shops). As a basic step in data collection, we checked the suitability of the questionnaire through a pilot test. We revised the questionnaire to address the loopholes detected in the pilot survey. During the fieldwork we faced several problems in collecting information. Most complications arose from the availability of the head of the household. In many cases hired labour was responsible for all dairy related activities; this meant that the head of the household didn't have the appropriate information such as the time spent performing different dairy activities. Wherever possible, we tried to collect relevant information from the most appropriate people. We collected information on socioeconomic characteristics, landownership, cropping pattern, agricultural production, assets ownership, milk production and consumption, milk marketing choices, input output quantities, and prices. Nevertheless, there are wide regional, social, lingual, and cultural differences between the two regions of Punjab, which may have some effect on the quality of data. After accounting for missing observations from the data and unavailability of alternative choices in the village, we are left with 307 respondents.

4.3.1 Farmers' participation in marketing channels

Table 4.1 summarises the distribution of farmers associated with modern and traditional marketing channels in two channels and two regions. Out of a total of 307 dairy farmers in the data, 83 farmers (26 percent) sell milk to modern milk supply channels and 224 farmers (84 percent) sell milk to traditional channels.

Table 4.1 Household distribution: marketing channels and regions

Regions	Modern Supply Channels	Traditional Supply Channels	Total
North Punjab	32	140	172
South Punjab	51	84	135
Total	83	224	307

[4] Union Council is a small part of district that has its own local government, [5] Mauza is a part of the Union Council that consists of a few villages and has its own revenue officer

Important characteristics of households in the two regions of Punjab are presented in Table 4.2. This illustrates that average age, experience, education, household size, and herd size are higher in South Punjab, while milk output per day (litres), quantity of milk sold per day (litres), and the percentage of crossbred and imported cows in the herd are higher in North Punjab. The price of milk per litre in modern milk supply chains and traditional supply chains is higher in North Punjab.

Table 4.2 Household characteristics in two regions of Punjab

Variables	North Punjab		South Punjab		Total	
	Mean	SD	Mean	SD	Mean	SD
Age of head of household (years)	44.2	11.38	46.1	10.80	45	11.15
Experience of head of HH (years)	16.1	8.71	16.5	8.96	16.3	8.81
Education level of head of HH	1.89	1.41	2.42	1.33	2.1	1.11
Household Size (number)	8.68	3.34	8.94	3.35	8.8	3.34
Herd Size	16.93	11.45	20.35	12.47	18.44	12.02
Milking Herd	5.01	4.34	5.38	3.09	5.17	3.84
Buffalo	11	8.13	8.86	8.14	10.05	9.18
Local Cattle	2.17	3.33	3.80	7.24	2.89	5.46
Crossbred	2.17	4.40	4.63	6.83	3.26	5.73
Imported Cattle	1.58	3.29	3.04	6.23	2.22	4.86
Crossbred and Imported Cattle	3.75	5.61	7.68	8.76	5.49	7.42
Percentage of Cross and Imported Cattle	19	22.25	36.3	31.89	26.6	28.22
Cow percentage in herd	33.16	25.36	56.3	30.52	43.38	30.00
Milk price in traditional channels (Rs/ltr)	46.47	8.33	41.5	5.46	44.60	7.75
Milk price in modern channels (Rs/ltr)	41.12	5.64	39.4	4.37	40.09	4.94

Table 4.3 describes the socioeconomic and farm related characteristics of farmers in formal and informal markets, and an independent sample t-test is conducted to test the difference between characteristics of both marketing channels. This shows that the age of farmers in modern market channels is less and their experience is greater than that of farmers in traditional channels. However, the age and experience of the head of the household does not vary significantly among different market channels. The educational level of farmers in modern market channels is significantly higher, which may suggest a tendency towards early adoption of new marketing channels with higher education levels. The average family size in traditional channels (9) is statistically higher than modern market channels (8.24).

It further shows that the herd size in modern milk channels (21.65) is higher than traditional channels (17.25) and is statistically different. It may points towards a tendency for large farms to sell milk to modern supply channels.

Table 4.3 Household characteristics of farmers on the basis of participation in two different milk supply channels in Punjab

Variables	Modern Channels		Traditional Channels	
Modern Channels = 1, Traditional Channels = 0, Mean = 0.26, SD = 0.44				
	Mean	SD	Mean	SD
Age of head of household (years)	44.84	10.84	45.15	11.28
Experience of head of HH (years)	17.13	8.49	16.07	8.93
Education level of head of HH	2.32	1.43	2.05	1.38
Household size (number)	8.24	3.39	9.00	3.30
Herd size	21.65	12.90	17.25	11.48
Milch herd	5.65	3.39	5.00	3.99
Buffalo	10.46	8.87	9.90	7.94
Local cattle	2.63	4.73	2.99	5.72
Crossbred	6.19	8.60	2.18	3.68
Imported cattle	2.34	4.74	2.18	4.91
Crossbred and imported cattle	8.54	9.06	4.36	6.38
Percent of Cross and imported cattle	37.11	30.63	22.76	26.31
Percent of cows in herd	52.27	31.61	40.10	28.77
Milk output (liter/day)	54.14	42.03	39.45	29.17
Milk sold (liter/day)	45.20	40.68	31.21	28.31
Sold milk percentage	77.12	13.85	70.57	17.73
Price of milk (Rupees/liter)	40	4.94	44.6	7.75
Distance to city (km)	7.40	2.80	7.04	2.78
Distance to milk collection unit (km)	1.86	0.93	2.92	1.06
Distance to metalled Road (km)	0.35	0.48	0.46	0.62
Dairy farming land (acres)	3.30	1.99	2.90	1.83

The number of buffalo and local cows in the herd does not differ significantly between each market channel. However, farmers in modern marketing channels have more crossbred and imported cattle (8.54) than farmers in traditional channels and are statistically different. Modern milk supply channels promote high yielding crossbred and imported cows to reduce seasonal variations in milk production which occurs quite often in the buffalo milk production system (Sharma et al., 2009). Moreover, dairy herds belonging to farmers who use modern milk supply channels consist of 52 per cent cows, while for traditional channels the share of cows in the herd is 40 per cent.

The average milk production of farmers in modern supply channels (54.1 litres/day) is higher than the production of farmers in traditional channels (39.4 litres/day). The market surplus of farmers participating in modern channels is also higher. Nearly 77 percent of the total milk produced is marketed by farmers using modern channels, while 70 per cent is marketed through traditional channels. The price offered by modern supply channels (Rs40) is significantly lower than the price in traditional channels (Rs44.6).

The average distance travelled to the milk collection unit is statistically different and higher in the case of traditional marketing channels (2.92 km) compared to modern channels (1.86 km). The distance to a metalled road is found to be statistically lower in modern marketing channels (0.35 km) than traditional channels (0.46 km). The land use for dairy farming is lower in the case of farmers participating in modern milk channels (2.46) compared to traditional ones (2.90 acres). This could indicate a better use of resources by farmers participating in modern supply channels.

4.4 Methodology and empirical model

The logit model developed by Cox, (1958) and Walker & Duncan, (1967) is used in this study to estimate the factors influencing dairy farmers' decisions to participate in modern and tradition milk supply channels. In the binary logit model, the dependent variable (milk marketing channel) is a dichotomous variable (yes=1; no=0) and the independent variables are qualitative and quantitative. The probability of adoption can be expressed as follows:

$$\text{Probability of adoption} = P_{(y=1)} = \frac{e\beta_o+\beta_1 X_i}{1+e\beta_o+\beta_1 X_i} \quad (1)$$

The logit transformation of the probability of adoption P(y=1) can be expressed as follows

$$ln\left[\frac{p_{(y=1)}}{(1-p_{(y=1)})}\right] = \beta_o + \beta_1 X_i \quad (2)$$

Where *p* represents the probability of farmers to participate in modern milk supply channels, and β_{is} are the regression coefficients estimated by the maximum likelihood method. Equation (2) represents the logarithm of the odds when choosing milk marketing channels, conditional on the independent variables that are included in the model.

The interpretation of logit regression coefficients is less straightforward than the ordinary least squares model. The coefficients of logit regression represent the likelihood of an outcome depending on the increase or decrease of independent variables. A positive coefficient of independent variables increases the probability and vice versa. However, the marginal effects of independent variables on the probabilities are not equal to the coefficients. The marginal effects of each variable are computed using the following equation:

$$\frac{\delta p(Y)}{\delta X_i} = \frac{\beta X_i * \exp{[Z]}}{[1+\exp{(z)}]^2} \tag{3}$$

Z is the sum of coefficients, multiplied by the means of respective variables plus a constant term. The binary logit model does not assume linearity between explanatory and explained variables. It does not require a homoskedasticity assumption and also does not assume normally distributed variables.

Since the logit regression is a non-linear model, the normal R^2 measure for the goodness of fit is not valid. To measure the percentage of correct predictions, the predicted probability of adoption is calculated for each farm and is compared to the actual adoption decisions. The predicted probabilities of the logit model lie between zero and one. The model predicts adoption if the predicted probability is higher than 0.5, and assumes non-adoption otherwise. The binary logit model used in this study is specified as follows:

$$Y_i = f(\beta\, ; \chi_i) = f(\text{milk sold, cross and imported cattle, dairy farm land,}$$
$$\text{milk price, distance, payment, education, region})$$

Where, *Yi* is a dichotomous variable (modern channels = 1, traditional channels = 0) and X_i are the independent variables. Here, milk sold (litres) is the quantity of milk sold per day, cross and imported cattle are the number of these cattle in the herd, dairy farm land (acres) is the total land used for cultivation, milk price is the price of milk per litre in Rupees paid by different channels, distance is the distance in km from the milk collection unit, payment is the payment period (fortnight or less = 0, more = 1), education is the level of education (no education = 0, primary = 1, middle = 2, higher secondary = 3, bachelor = 4, master of higher = 5) and region is based on the cultural division of Punjab (North Punjab = 1, South Punjab = 0).

4.5 Results and discussion

Traditional market channels are considered to be the base category in the logit model. The results of logit regression are presented in Table 4.4. They show that the volume of milk sold, the number of cross and imported cows in the herd, and the regional dummy all have significant positive effects on the farmers' likelihood to participate in modern supply channels. The volume of milk sold increases the likelihood of farmers' participation in modern milk supply channels. This may suggest that farmers with large quantities of milk are more inclined towards using modern milk supply channels for a smooth supply of milk and less price fluctuations in the peak season. Moreover, modern milk supply channels also offer relatively higher prices to large farms. These findings are consistent with the study of Sikawa & Mugisha (2011) who find that farmers who sell large volumes of milk prefer to participate in modern channels which are capable of absorbing larger amounts of milk. However, the small marginal effect of volume of milk sold may be due to the reason that buffalo milk producer prefer to sell milk to vendors or consumers because of high demand of buffalo fresh milk due to its high fat contents.

Farmers who have a higher share of cross and imported cattle are more likely to sell milk to modern milk supply channels; this could be explained by their expected technological advancement and attempt to avoid the seasonal drop of milk which happens in the case of buffalo milk production. Another possible explanation could be that farmers who are primarily cow milk producers are also more likely to join modern milk supply channels due to a lower preference for cow milk by consumers on account of its low fat content. However, the marginal effect of cross and imported cattle on farmers' participation in modern milk supply channels is quite small (0.6 percent).

The regional dummy also has a significant positive effect on the likelihood of farmers' participation in modern supply channels. The rationale here is that modern channels are more concentrated in North Punjab; as a result, farmers in the north have better access to modern supply channels and competition among different supply channels ensures better prices and incentives for farmers to participate. The marginal effect of the regional dummy is high, indicating that farmers in North Punjab are 12 percent more likely to participate in modern supply channels.

The negative coefficient of the price of milk implies that an increase in the milk price reduces the likelihood of participation of farmers in modern supply channels. One possible interpretation of this is that price is the basic driving force in the selection of marketing channels by small and medium sized farms. Lower prices of milk offered by modern marketing channels, in comparison to vendors and consumers, reduces the likelihood of farmers using modern channels.

Nevertheless, the marginal effect on the non-participation of farmers in the modern supply channel is quite low (0.9 percent). This could also indicate that farmers with higher volumes of milk are more likely to sell to modern supply channels to ensure smooth delivery. However, these findings are inconsistent with the study of Sharma et al. (2009) who suggest that farmers are more likely to use modern milk supply channels irrespective of the lower prices offered. They find that modern channels have price stability when compared to traditional ones, increasing the likelihood that farmers will choose them.

The distance to the milk collection unit lowers the likelihood to choose modern supply channels. Consequently, there is a higher negative marginal effect (12 percent) on the participation of farmers in modern channels. This suggests that if the distance to the milk collection unit is increased, small and medium sized farms do not supply milk to modern market channels because of increasing transport costs and time required for transportation. In some cases when small farmers don't have easy access to milk supply channels due to lack of roads they either consume all milk at home or sell it to rural consumers at extremely lower prices which discourages dairy farmers. However, large farms may also find it difficult to transport large quantities of milk over greater distances as transportation costs will become an issue for them too. As a result, an increase in distance discourages both small and large farms from participating in modern supply channels. These results are consistent with the findings of Sharma et al. (2009) and Omiti et al. (2007) who find that the channels associated with long distance have higher transport costs and are not preferred as they reduces farmers' gross margins.

The payment procedure reduces the likelihood that farmers will participate in modern supply channels and has a strong negative marginal effect (26 percent) on modern channels. Farmers are less likely to participate because modern channels tend to make payments monthly and transfer payments through banks. This creates difficulties for small and medium sized farms in meeting their day to day expenses. Farmers are not so familiar with banks and are usually hesitant to deal with them. Moreover, monthly income from milk sales is not high enough to be kept in banks. Thereby, lengthy payment periods and difficult payment procedure discourage small and medium farmers' participation in modern milk supply channels. However, vendors and consumers make weekly payments and also give early payments in the case of an emergency. For small and medium sized farms, it is easy to sell milk to traditional milk supply channels. These findings are consistent with the study of Sikawa & Mugisha (2011) who find that farmers prefer to sell milk to market channels who make immediate cash payments, necessary to fulfil farmers' daily financial needs. However, these findings are inconsistent with the study of Staal et al. (2006) who find that farmers are less likely to sell milk to those channels who make cash payments.

Table 4.4 Logit model estimates of milk marketing channels

Independent Variables	Regression coefficients		Marginal effects	
	Coefficients	Standard Error	Coefficients	Standard Error
Constant	4.636***	1.33	-	-
Milk sold (ltrs)	0.017**	0.00	0.002**	0.00
Cross and imported cow	0.048**	0.02	0.006**	0.00
Dairy farm land	-0.263**	0.13	-0.032**	0.01
Milk price (Rs/ltr)	-0.074***	0.02	-0.009***	0.00
Distance to MCU (km)	-1.009***	0.19	-0.126***	0.01
Payment method	-2.097***	0.38	-0.262***	0.03
Education	0.158	0.11	0.019	0.01
Region	1.032***	0.40	0.129***	0.04
Number of observations	307			
Log likelihood	-120.58			
Pseudo R2	0.32			

The size of land used for dairy farming reduces the likelihood that farmers will participate in modern milk supply channels by 3.2 percent. This needs careful interpretation. The possible rationale behind this finding is that farmers who use more land for cultivation of fodder and dairy activities are relatively less efficient in their use of resources and are more traditional. Besides this, farmers with large shares of buffalo, which have more fodder requirements than cows, might use more land for cultivation. To the best of our knowledge, farmers with buffalo are more inclined towards traditional channels because of the high demand for fresh buffalo milk due to its high fat content. Such farmers are less likely to participate in modern milk supply channels.

Table 4.5 shows that the logit model correctly predicts 86 percent of the overall observed values, with 63 percent correct predictions for participation in modern supply channels and 95 percent correct predictions for traditional market channels.

Table 4.5 Classification of predicted outcomes of logit model

Predicted			
Classified	Modern = 1	Traditional = 0	Total
Modern = 1	52	12	83
Traditional = 0	31	214	224
Total	83	224	307
Percentage correctly predicted	62.6 percent	94.6 percent	85.8 percent

4.6 Conclusions and recommendations

Although modern milk supply channels are expanding their base, traditional milk supply channels still have the major share in milk markets in Pakistan. Major hurdles in modern supply channels stem from small and scattered milk producers contributing to an increase in milk collection costs. Traditional milk markets are effective in terms of access to small farms and urban consumers. However, growing consumer concerns about the quality of milk and hygiene related issues with traditional milk channels are increasing the demand for processed milk. Urbanisation has been growing at a huge pace in Pakistan and has increased the demand for fresh milk in urban centres, leaving traditional channels unable to fill the gap. These factors have created an enormous space for modern milk supply channels in Pakistan. In the early 2000s, many new players entered into the milk processing industry, with the number increased from 2 in the 1990s to 21 in 2010. This has changed the scenario of milk supply markets in Pakistan.

In this study we analyse the factors influencing the choice between modern and traditional milk marketing channels by using the survey data of dairy farmers in Punjab, Pakistan. We have found significant differences in terms of herd size, cross and imported cattle in the herd, milk sale volume, milk output volume, price, and educational levels of farmers in modern and traditional milk channels. The volume of milk sold and number of high quality breeds in the herd both have a significant effect on farmers' participation in modern supply channels. This shows that technologically advanced and large farms tend to opt for modern supply channels. Furthermore, with the commercialisation of the dairy sector and an increasing demand for quality milk, the participation in modern supply chains will increase.

However, milk prices, the distance to the milk collection unit, and the payment procedure all negatively affect farmers' participation in modern supply channels. This suggests that farmers with a small quantity of milk sales are inclined to use those market channels which offer higher prices and collect milk at the farm gate which increases their profitability and reduces transport costs. Furthermore, traditional milk supply channels make early payments and sometimes make advance payments that encourage farmers to sell milk to these channels. However, modern supply channels make monthly payments and also transfer money through banks which discourages small farmers to participate in these channels. The growth of modern milk supply channels by and large depends on the development of the milk collection infrastructure, competitive prices, and rapid and easy systems of payments.

Considering the findings of this study; if farmers are provided with advanced dairy technology and are given institutional support, milk production and farmers' capabilities to manage resources could both be enhanced, shifting farmers towards commercialisation. Easy access to the market by improved market infrastructure requires investment in infrastructure to develop farm to market linkages and is a necessary step in order to enhance quality milk supply. Moreover, milk prices and payment methods are important factors in the choice of market channels and selling milk, and hence can be used as a policy instrument to enhance farmers' levels of commercialisation.

Chapter 5

Summary

Pakistan's dairy sector has experienced a remarkable expansion over the past 25 years. This expansion is marked by increased milk production, an improvement in herd breed structure, enhanced extension services, and the expansion of milk collection channels. In comparison to the early 1980s when selling milk was a social taboo, more than 12 billion liters of milk are now marketed through different channels. This has led the dairy sector from subsistence farming to a commercialised activity. The contribution of the dairy sector to Pakistan's economy is enormous in terms of share in national GDP and share in the total labour force. However, despite all of the improvements, Pakistan is unable to meet its milk requirements and is a net importer of milk and milk based products.

There are many challenges to the dairy sector in terms of productivity and efficiency of farmers. These include the difficulty in using advanced production technology due to the small scale of farms, the difficulty in providing extension services to scattered farmers, and the collection of milk through hygienic means from remote farmers. As a result, evaluating the efficiency performance of dairy farmers in Pakistan is a subject of great importance. Growth in productivity is attributed to the use of new production methods and efficiency improvements. However, improving efficiency is the key way to increase farm productivity in the absence of technological development.

We conducted a study in Pakistan's Punjab province, and collected information from resident dairy-crop farmers. Punjab is the country's largest province in terms of share in both national GDP and agriculture. The agriculture sector plays a pivotal role in the province's economy, taking on a 28 percent share. Punjab is famous for its breeds of buffalo (Neeli Ravi) and cattle (Sahiwal). It contributes 56 percent to the total national herd and 65 percent to the country's total milk production. Consequently, the dairy sector plays a significant role in Punjab's economy. Agriculture in Pakistan is a combined activity of dairying and cropping, so we collected information from dairying-cropping mix farmers.

In this study, we start by analysing the productivity and efficiency of dairy farmers with a focus on the determinants of technical efficiency by employing the stochastic frontier function.

Secondly, we estimate the efficiency of farmers within a multi-output framework and consider the factors affecting the efficiency of farmers by using the translog output distance function. Finally, we investigate the determinants of farmers' participation in different milk supply channels by applying the binary logit model. This dissertation contributes to the literature by giving a province-wide picture of the performance of dairy farmers in Pakistan and the roles of different factors including extension services, rented land and credit. Moreover, this study represents the first attempt of its kind to evaluate the performance of Pakistan's dairy farmers in a multi-output situation. Finally it adds to the literature by investigating the determinants of the changing milk marketing structure in Pakistan.

5.1 General findings

In Chapter 2, we estimate a Cobb-Douglas Stochastic production frontier with a technical efficiency model to determine the importance of inputs in dairy production and the farm-specific characteristics that explain the differences in technical efficiency across the market oriented dairy farms in Pakistan. We review the progress of the dairy sector in Pakistan with a special focus on extension and veterinary services, improvements in the breeding structure of herds, and milk collecting facilities. The results of the study show that extension and veterinary services, and improved cattle breeds play a significant role in the technical efficiency of farmers. However, the role of modern milk collection channels is not statistically significant. Furthermore, experience plays a significant role in decreasing the technical inefficiency of farmers while age reduces the technical efficiency of dairy farmers. The results show that the mean technical efficiency of dairy farmers in Pakistan is 0.85, which implies that output can be increased by 15 percent by enhancing the technical expertise of farmers.

The study's findings suggest a need for extended and improved extension services alongside quality training programmes for dairy farmers to ensure proper farm management. It is also necessary to provide improved breeds of cattle and buffalo to curtail the huge plunge in milk production in the summer season. Moreover, in order to enhance commercialisation of the dairy sector and increase profitability of farmers, adoption of modern farm technologies and expansion of modern milk supply networks to remote areas are important policy instruments.

In chapter 3 we estimate the efficiency of dairy farmers in a multi-output, multi-input paradigm. We first review the progress of the agriculture sector in Pakistan. The study employs the translog output distance function approach to estimate input substitution and complementary effects, and identify the determinants of technical inefficiency of dairy farmers in

Pakistan. The results of the first order partial elasticities for all inputs reveal that the milk output increases monotonicitly. The cross-term effects of inputs point towards substitutions effects between inputs, including: labour and land, and complementary effects between irrigation and labour, and seed and land on milk production. The negative complementary effect between labour and land suggests that with an increase in landholdings, farmers shift towards mechanisation. Meanwhile, the positive complementary effect between labour and irrigation indicates that farmers with a traditional system of irrigation require more labour.

The empirical results of the technical inefficiency model show that the average estimated technical efficiency of dairy-crop farmers is 79 percent, implying that opportunities exist to expand production by 21 percent without any additional resources, given the current level of production technology. We find that extension services increases the technical efficiency of farmers by imparting technical skills and creating awareness about advanced farm management practices, thereby ensuring enhanced efficiency in the long-term. Access to credit and rented land positively affect the efficiency of farmers. This suggests that farmers having access to credit achieve higher efficiency levels by timely purchase of inputs and also adopting modern farm technology and shifting towards farm mechanisation. Rented-in land may provide a more efficient farm size and better use of labour, resulting in an enhanced technical efficiency. However, although crop diversification decreases the technical inefficiency of farmers, it does not have a statistically significant effect.

In Chapter 4 we analyse the factors that affect farmers' decisions to participate in modern or traditional milk marketing channels in Punjab. In Pakistan, modern milk supply channels are expanding their base but traditional milk markets still make up the major share of Pakistan's milk markets. However, growing consumer concerns about the quality of milk and hygiene related issues with traditional milk channels are increasing the demand for processed milk. These factors have created an enormous space for modern milk supply channels in Pakistan.

We find significant differences in terms of herd size, cross and imported cattle in the herd, milk sale volume, milk output volume, price, and educational levels of farmers in modern and traditional milk channels. Both the volume of milk sold and the high quality breeds in the herd have a significant effect on farmers' participation in modern supply channels. However, milk prices, the distance to the milk collection unit, and the payment procedure all negatively affect farmers' participation in modern supply channels. The findings of the study suggest that the use of advanced dairy technology and institutional support could enhance milk production and farmers' capabilities of managing resources, hence potentially shifting farmers towards commercialisation. Easy access to the market by improved infrastructure requires investment in rural infrastructure and is a necessary step for enhancing the milk supply. Moreover, milk prices and payment methods are important factors in the choice of market channels and selling milk, and hence can be used as a policy instrument in enhancing farmers' levels of commercialisation.

This study provides sufficient insight into dairy sector of Pakistan to devise strategies to improve productivity and reduce technical inefficiencies of farmers. Pakistan dairy sector is highly integrated where same factors of production are used for producing multiple agricultural outputs. Such pattern reduces the cost of production by using outputs of crops in dairying and *vice versa*. Dairy sector is also experiencing changing milk marketing structure due to growing concerns about quality of milk and increasing demands of milk in urban centres. However, drastic reduction in milk supply in summer season, small and conventional farming and poor access to markets are challenges needed to overcome. Improvements in production, efficiency and profitability of dairy farmers depend on the access to quality services and investment in dairy sector by shifting it from conventional to modern farming and from subsistence to commercialised sector.

5.2 Policy implications

With the changing dairy structure, growing concerns about the quality of milk, and increasing urbanisation, there is a noticeable increase in the demand for quality milk and milk products. An immediate implication of this study is that, in order to enhance the efficiency of dairy farmers, an extended and improved program of extension and veterinary services is required to enhance both the technical and managerial skills of farmers. Such a program should focus on the efficient use of resources and labour in a mixed dairy-cropping agriculture system. Extension services should also focus on creating awareness about modern farm technologies and educating farmers about modern crop rotation practices so that farmers can select better combination of crops to enhance their profitability.

Access to credit is an important factor to enhance mechanisation, develop modern farming practices and in time purchase of inputs. In Pakistan, where farmers usually rely on old practices of dairying and cropping, a targeted credit program to enhance mechanisation in dairying and cropping is necessary to enhance productivity and efficiency in the long term. A long and extreme summer season in Pakistan creates severe challenges relating to water and the input requirements for farmers; an effective credit program can assist farmers to cope with these challenges.

Pakistan faces severe challenges due to the extreme drop in milk production in the summer season. There is a dire need to focus scientific research on the development of improved cattle and buffalo breeds that are capable of tolerating severe weather conditions and fulfilling the increasing demand for milk. Moreover, due to the old structure of dairying, farmers have no technical knowledge of breeding practices; this results in unwanted cross-breeding of different cattle (and buffalo) breeds, and ultimately damages the quality of the herd. Extension service programs should also focus on imparting knowledge about breeding practices.

Rented land plays an important role in enhancing farmers' efficiency and productivity by providing more appropriate farm size along with a more efficient use of labour. In Pakistan, renting of agricultural land is not regulated and farmers have no security in case of both renting in and renting out land. Policy makers should focus on the development of land rental markets to increase agricultural production and enhance technical efficiency of farmers.

Growing concerns about the quality of milk and an increasing demand for milk in urban centres has enhanced the expansion of modern milk supply channels. However, Pakistan is still unable to harness the full potential of its dairy sector; Traditional milk supply channels are unable to meet demands and modern supply chains have less access in remote areas. Policies should focus on the development of milk supply chains to market all the milk produced in remote areas by offering incentives to milk supply channels and improving infrastructure in remote areas. Milk collection can also be enhanced by making farmers' cooperatives.

5.3 Research limitations and further studies

Since we have only focused on one province using data from just 345 farmers, future research using more data and considering other provinces could give more robust results and help in highlighting regional differences in production systems. Moreover, we have only collected data on milk production from dairy farms. Further research can focus on meat and other homemade milk products for a deeper understanding of the production system.

There is great potential for the efficient use of labour in dairy-cropping farming systems in Pakistan. In chapter 4, we find substitutions effects between labour and land, and complementary effects between labour and irrigation. Further empirical research could potentially un-

unearth the reasons that prevent efficient use of labour; such reasons could lie with a lack of farm management skills or some other factors causing inefficient labour use.

Considering the changing milk marketing structure in Pakistan, we have only focused on the determinants of farmers' participation in different milk marketing channels. However, there is a dire need to gain an in depth understanding of the structure of modern and traditional milk supply channels. Further research could focus on the performance of different milk supply channels in Pakistan.

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Appendix

Socio-economic characteristics of Dairy Farmers in Pakistan (Questionnaire)

GPS Location of dairy farm	Latitude:	Altitude:

1. Questionnaire code ______ **2. Name of interviewer** _____________________
3. Date of interview (day/month/year):____ / ___ / _____

4. Location details

4.1 Country__________ **4.2** Province________ **4.3** District_________ **4.4** Tehsil__________

4.5 Name of union council___________________ **4.6** Name of village________________________

5. Basic household characteristics of dairy farmers

5.1 Name of respondent:

5.1.1 First Name:__________ **5.1.2** Middle Name:________ **5.1.3** Last Name:______________

5.2 Role of respondent at home ☐Head of household ☐Member of household

5.3 Gender ☐Male ☐Female

5.4 Can you read or write? ☐Yes ☐No

5.5 Mobile (optional):_______________ **5.6** Ethnicity___________________________

5.7 Is your family migrated? yes☐ no☐ **5.8** How long in total have you been a dairy farmer__ (yrs)

5.9 How many other farmers are in the village _________________________

6. Access to water and electricity

6.1 What is the main source of drinking water in your HH?

1. ☐Bottled water 2.☐Tab water 3.☐Hand pump 4.☐Motor pump 5.☐Well
6.☐River 7.☐Lake 8.☐Pond 9.☐Others, Please specify

6.2 What is the main source of power (light) in your home/farm?

1.☐Electricity 2.☐Generator 3.☐Kerosene lamp 4.☐Others, please specify

6.3 How long is electricity load shedding per day? _____ hr

6.4 How do you manage it? By Generator☐ Peter engine☐ UPS☐ nothing☐ Others☐

6.5 How much it costs more per months? ___________(Rs)

7. Access to basic social facilities

Facility	Available Yes, No	Distance from house?(km)	Time require (min,hrs)
Schools (primary and secondary)			
Health (clinic/hospital)			
Bank			
Post office			
Police station			
Common Market			
Agricultural market			
Agri. Extension Services			
Veterinary Hospital			
Road (metalled/non-metalled)			

8. Salary of employee at village level (Rs/day)

Year	Gender	
	Male	Female
2012 (Rs/day)		
2011 (Rs/day)		

9. Land Ownership

9.1 How many acres of land do you have? Own:___ Rented in:_____ Rented out: ____ Total: _______

9.2 What is the rent of land/acre? ___________ (Rs)

9.3 How many plots of land? ______________

9.4 What type of agricultural activities you do? 1. ☐Only dairy farming 2. ☐crop and dairying farm

9.5 How many acres of land are used for dairy farming? _______

10. Machinery

Do you have agro-machines? Yes☐ No☐

Type	No.	Model	Since how long you have it?	Price of New	Annual Costs	Price of used
Tractor (HP)						
Tractor (HP)						
Tractor (HP)						
Trolley						
Thresher						
Plough						
Tiller						
Rotavator						
Disc harrow						
Drill machine						
Spray machine						
Chisel						
Blade						
Others						

11. Access to veterinary services

11.1 Is there any govt. veterinary clinic in your area? yes☐ no☐

11.2 How long it takes to veterinary clinic? _____ mint/hrs

11.3 Is there any private clinic in your area? yes☐ no☐

11.4 Does V/o recommend you any practices? Yes ☐no☐

11.5 Do you practice the recommended procedure? Yes☐ no☐

11.6 How many times during last year you visited? ___

11.7 How many times per year V/o visits your farm? __

11.8 Are you satisfied to the veterinary service? yes☐ no☐

11.9 If no, Why? 1. ☐Not available in time 2. ☐Costly 4. ☐others___

11.10 Most of the time you check your animals from? 1. ☐Govt. 2. ☐Private

12. Access to extension services

12.1 Are the extension services, technical assistance and educational programs for milk production and herd care available on a regular basis? yes☐ no☐

12.2 Have you or your family member attended any educational/training program? yes☐ no☐

12.3 If yes, how many times? ____

12.4 When_____________(month/year)

12.5 What was the purpose? _________________

12.6 How many times govt. extension worker visited you during last one year? ____________

12.7 Whom do you consult with when you have problem in your Herd?

1. ☐Veterinarian	2. ☐Salesmen	3. ☐Magazine
4. ☐Other farmers	5. ☐Consultant	6. ☐Private extension agents

12.8 Are you satisfied to the extension service? yes☐ no☐

12.9 If no, Why? 1. ☐ Not available 2.☐Not available in time 2. ☐Costly 4. ☐others___

13. Sources of information (Please tick thee important ones)

1.☐ Office call	2.☐ Trader	3.☐ Newspaper	4. ☐Extension /veterinary officer	5.☐Processors
6.☐ NGOs	7.☐ Vendor	8.☐ Neighbors	9.☐Family, friends and relatives	10.☐Framers
11.☐ Magazines	12.☐ Radio	13.☐ Television	14.☐ others, please specify _______	

14. Herd Structure

14.1 Herd basic information

14.1.1 Average number of calves per cow __ **14.1.2** Average number of calves per buffalo___

14.1.3 Average age of cow to be in herd _____ **14.1.4** Average age of buffalo to be in herd ___

14.1.5 Average lactation period of cows in herd: Local______, Cross bred_____, Imported_____

14.1.6 Average lactation period of buffalo in herd_____

14.2 Herd distribution

Animals	Type	No.			Value	How many rented?
		Local	Imported	Cross-bred		
Cow	Cows in milk and dry					
	Heifers 1 to 2 years					
	Heifers over 2 years					
	Other dairy cattle (Bulls, steers, calves)					
Buffalo	Buffalo in milk and dry					
	Heifers 1 to 2 years					
	Heifers over 2 years					
	Other dairy cattle (Bulls, steers, calves)					
Sheep						
Goat						

14.3 Herd breed structure

Milking Animal	**Local**	Milk/ Day (lit)	Month of lacta-tion	**Imported**	Milk/ Day (lit)	Month of lactation	**Cross-bred**	Milk/ Day (lit)	Month of lactation
Cow									
Buffalo									

14.4 Herd flow structure

Animal	**year**	**Born**	**Bought**			**Sold**			**Died**	**Slaughtered**
			Local	Imported	Cross-bred	Local	Imported	Cross-bred		
Cow	2012									
	2011									
	2010									
Buffalo	2012									
	2011									
	2010									

15. Access to credit

Sources of credit	Year	Amount of Credit (Rs.)		Dura-tion	Interest rate	Year of credit borrowing	What was the purpose?
		For dairy	For farming				
Commercial banks							
Agricultural bank							
Credit Unions							
NGOs							
Shopkeepers							
Milkman							
Milk processors							
Relatives							
Friends							
Money lender							
Others							

16. Dairy feed usage information

Inputs	Turns/day	Amount Kg/day	Cost (Rs/Kg) or (Rs/day)	Cost/month	No. of days/months/yr
Fodder from own field					
Fodder from private field					
Fodder from market					
Husk					
Sugarcane leaves					
Concentrates					
Salt					
Watering			---	--	--
Others					

17. Fodder production and feed usage information

17.1 What is the source of your dairy cattle feed? 1. ☐ Own production 2. ☐ Purchased 3. Both

17.2 Which crop residue do you use for feed? 1. ☐Wheat straw 2. ☐ Rice straw 3. Both

17.3 Do you grow fodder crops? ☐Yes ☐No

17.4 If no, what are your major reasons for not growing fodder crops? (rank three most important)

1. ☐Insufficient land 2. ☐ Insufficient labor 3. ☐ Insufficient inputs (seed, fertilizer, and cash)
4. ☐Feed for animals is adequate 5. ☐ Insufficient information

17.5 Do you buy any feed supplements for your animals? Yes No

17.6 If yes, Why do you buy these feed supplements most of the time? (rank three most important)

1. ☐For lactating cows 2. ☐For pregnant cows
3. ☐For male calves 4☐. For female calves 5. ☐ For beef cattle

17.7 Which feed supplements do you buy?

1. ☐Oil seed cake 2. ☐ Cottonseed cake 3. ☐Wheat and corn bran and middling

17.8 When you want to dispose your animals, what criterion do you use? (Rank three most important)

1. ☐ Old age 2. ☐ Sickness 3. ☐ Low milk production 4. In☐fertility

17.9 What sources of water are you using for your dairy animals?

1. ☐Pipeline water 2. ☐The nearby river

3. ☐Pond 4. ☐Hand pump 5. ☐Motor pump

17.10 What is the main constraint for your livestock production? (rank three most important)

1. ☐Feed shortage 2. ☐High feed prices 3. ☐Disease 4. ☐High medicament cost

5. ☐ Market availability 6. ☐Shortage of land for grazing or forage development

7. ☐ Lack of capital 8.☐ Inefficient breeding services 8. ☐ Others ____________

17.11 What is the average price of fodder in your area?

Green fodder: Summer ___________ (Rs.)Winter_____________(Rs.)

Dry fodder Summer ___________ (Rs.)Winter_____________(Rs.)

17.12 What is the average cattle feed (Concentrate) price per kg? Price ______________ Rs.

18. Miscellaneous dairy related Costs

Year	Medication		Vaccination		Insemination		Cost of chains, sickle/yr	Cost of repairing of cutting machine/yr
	No. of Cattle got sick	Total cost	No.	Total cost	No.	Total cost		
2012								

19. Time distribution of labour on different dairy activities

19.1 What type of grazing system are you using?

1. ☐Zero grazing 2. ☐Semi-grazing 3. ☐Full grazing

19.2 If option 2 and 3 then, how many hours per day? ___

19.3 How many Persons/day bring herd for grazing? _____

Activities	No./day	Time/turn	How many days/month/ Year?	Family labour		Hired labour	
				M	F	M	F
Cutting of grass from own field							
Cutting of grass from private field							
Transportation of grass from field or market							
Transportation of Sugar cane leaves							
Crushing of grass							
Distribution of grass							
Transportation+ Distribution of Husk							
Formation+ Distribution of Concentrated							
Watering							
Milking							
Cleaning							
Shifting and tethering of an-imals							
Transportation of milk							
Others							

20. Distribution of family and hired labour

Type	Total persons who work daily	Family		Hired	
		M	F	M	F
For Dairy only					
For Farming only					
Mixed labour					

21. Total cost of hired labour

Labor	**No. of employees (yearly basis)**	Salary/person			**No. of employees (monthly basis)**	For how many months	Salary/ person (Rs)	**No. of employees (daily basis)**	For how many days	Salary/ person (Rs)
		Rs.	Grains (100kg)	Total salary (Rs)						
Only for Dairy										
Only for Farming										
Mixed labor*										

22. Cost of inputs (for fodder, cereals and cash crops)

Crops		Total area	Plough		Sowing		Seed cost		Pesticides cost			Herbicides cost		
			Turns	Cost/turn	Turns	Cost/turn	Kg/acre	Price/Kg	No. of turns/ acre	Lit/ turn	Price/lit (Rs)	No. of turns/ acre	Lit/ turn	Price/lit (Rs)
Fodder crops														
Farm crops														

Cost of inputs (continue)

Crops		Total area	**Manures**		**Fertilizers cost**								Cost of Harvesting
			No. of trollys/ acre	Cost/tr olly	DAP		Urea		Potash		Others		
					Bags/acre	Price/Bag	Bags/acre	Price/Bag	Bags/acre	Price/Bag	Bags/acre	Price/Bag	
Fodder crops													
Farm crops													

23. Infrastructure (only dairy related)

Type	Total area (sq.m)	Year of construction	Made of bricks/mud	Repairing cost 2012 (Rs)	Total cost of construction (Rs)	
					Land	Other construction costs
Total covered area (sq.m)						
Total uncovered area (sq.m)						

23.1 If you purchased wooden beds what was their cost? __________ (Rs)

24. Other fixed costs (only dairy related)

Grass Cutting Machine			Electricity meter			cart			Motor pump			hand pump			Watering pond		
Year	Total cost	Current price	Year	Total cost	Current price	Year	Total cost	Current price	Year	Total cost	Current price	Year	Total cost	Current price	Year	Total cost	Current price
2012																	

25. Infrastructure (agri. farming related)

Total covered area (sq.m)	Year of construction	Made of bricks/mud	Repairing cost 2012 (Rs)	Total cost of construction (Rs)	
				Land	Total cost of construction (Rs)*

26. Other costs (only agri. faming related)

Tube well			Cemented Water course			Electric meter			Electricity bill (only of farming excluding irri-gation)			Miscellaneous costs
Year	Total cost*	Current price	Year	Total cost	Current price	Year	Total cost	Current price	Year	Total cost	Current price	
2012												

*It includes cost of bricks, cement, pipe, pump, belt, pulley and labor etc.

27. Output data (Dairy farming)

27.1 Milk production

	Period of milking	No. of Milking Animals	Milk/day (liters) of farm	Milk sold lit/day	Price/lit
Cow	Jan-April				
	May-August				
	Sep-December				
Buffalo	Jan-April				
	May-August				
	Sep-December				

27.2 Sale of manure

year	Manure (Ton/month/yr)	Distributed in owns field	sold	Price (Rs/ton/100kg)
2012		☐	☐	

27.3 Sale and Purchase of animals

Type	Animals sold in 2012 (No.)	Total price (Rs)	Animals purchased in 2012 (No.)	Total cost (Rs)
Cow				
Buffalo				
Sheep and goat				

28 Output data (agriculture farming)

crops	Total area	Produce/Acre (100kg/mounds)	Total produce (100kgs/mounds)	Price/100kg Or mounds	Total output (Rs)	Husk sale (Rs)

29 Milk marketing information

29.1 What is the average price of milk in your area?

If sold to**:** Consumer_____, Milkman ____, Shopkeeper_____, Processor's Unit_____ (Rs)

29.1 Since how long you are selling the milk? ________years

29.2 Which transport means do you use to transport milk for sale?

1. ☐Public transport 2. ☐Traveling on foot 3. ☐Own transport

29.4 What it the price of milk in your area? Cow ______Rs/liter Buffalo ______Rs/liter

29.5 Which method are using for the delivery of your milk?

1. ☐ Taking to the market 2. ☐Collected by consumers or purchasers

29.6 If Own transports, what is that? 1. ☐Bicycle 2. ☐ Motorcycle 3. ☐ Animal 4. ☐Others______

29.7 Do you receive milk payment in time and regularly? 1. ☐ Yes 2. ☐No

29.8 How frequently do you receive milk payment from Milk processor/milkman?

1. ☐Daily 2. ☐ Weekly ☐Fortnight4. ☐ Monthly

29.9 Any processor has purchasing point in your area? Yes☐ NO☐

29.10 How long ago first processor has opened purchasing point in your area? _______

29.11 How many processors have purchasing points are in your area? _____________

29.12 Which processors? Specify their name please.

Processor1_________, Processor2 _________, Processor 3, ___________, Processor4_______________

29.13 How long each processer's collecting point is from dairy unit?

Processor1__________, Processor2____________, Processor 3, ____________, Processor4___________

29.14 Is there any benefit to farmer of processor to enter in market? ___________________________

29.15 Is there any price difference between different processor? ______________________

29.16 How much? ________________ (Rs)

29.17 Do you think processors entrance has affected in better way on your selling of milk pattern and price?

1. ☐Yes 2.☐ No 3.☐ Don't know

29.18 Is there any shift in your selling pattern from your traditional customers to new one?

Yes☐ No☐

29.19 If yes!

New / Old	Consumer	Milkman	Shopkeeper	Processor	Others
Consumer	---				
Milkman		---			
Shopkeeper			---		
Processor				---	
Others					---

29.20 What were the good reasons in shift of new customer? (Please rank three most important)

1. ☐ Good price 2. ☐ Easy to sale 3. ☐ Timely payment 4. ☐ Timely collection
5. ☐ Relationship 6. ☐ Others, please specify

29.21 What were the dissatisfactions regarding old customer? (Please rank three most important)

1. ☐ Irregularity of payment 2. ☐ Vendor discontinued 3. ☐ Low price for milk
4. ☐ Inappropriate measurement 5. ☐ Distant location of sales point (collection center)
6. ☐ Milk production decreased 7. ☐ Closure of collection

30. Sale of milk to different marketing channels

Milk Buyers	Per-centage 2012	Price/ liter	How long are you selling the milk to following custom-ers? (yrs)	What is the payment pattern? Daily. Weekly, fortnight, monthly	Fixed cus-tomers or temporary?	If fixed how many?
Consumer						
Milkman						
Shopkeeper						
Processor						
other						

31. Household information

31.1 Size of household

31.1.1 Do you have joint family system? Yes☐ No☐

31.1.2 Total members: Male: Female:

Relation of head of HH	Age	Education*	Main job	Govt/ private	Scale	Salary	Work in agri-culture farm Yes, No	If working on farm how much time spent	Work by ani-mal husbandry Yes, No	If working by ani-mal husbandry how much time spent
HH head										
Wife										
Son										
Daughter										
Father										
Mother										
Grandfather										
Grandmother										
Grandson										
Granddaughter										

*0=uneducated, 1=primary, 2=middle, 3=high school, 4=bachelor, 5=masters, 6=higher

31.2 Have any children left home? Yes☐ No☐

No.	Gender	Age	Education	Job	Reasons of leaving

31.2 Head of the HH is farm manager Yes☐ No☐

31.3 If not, who is the farm manager? ____________________

31.3 The HH/farm manager acres other job Yes☐ No☐

31.4 If yes

Job	Place	Main job/ side job	earnings
Agriculture (except animal husbandry)			

31.5 The HH/farm manager is the member of any Union/political party/NGO. Yes☐ No☐

31.6 If yes

Name of institution	Any service receive from institution	Years of membership

31.7 The HH/farm manager has any political social role in village. Yes☐ ☐ No

31.8 If yes, what is that? ________________________

31.9 Since how long he/she is performing that? ________________________ (years)

32. Do you have a ……. (Please tick)

Type	Yes	No	If yes, How many
House with concrete floor			
Car/Van			
Motorbike			
Television			
VCR/DVD player			
Telephone			
Refrigerator			
Others			

Appendix 4:

D E C L A R A T I O N S

1. I, hereby, declare that this Ph.D. dissertation has not been presented to any other examining body either in its present or a similar form.

   Furthermore, I also affirm that I have not applied for a Ph.D. at any other higher school of education.

Göttingen, ...

....
(Signature)

....
(Name in block capitals)

2. I, hereby, solemnly declare that this dissertation was undertaken independently and without any unauthorised aid.

Göttingen,..

....
(Signature)

....
(Name in block capitals)