Estimation of Wheat Yield Response under different Economic, Location and Climatic Conditions in Punjab

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Estimation of Wheat Yield Response under different Economic, Location and Climatic Conditions in Punjab

By

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(Farhad Zulfiqar)

Dedication

I dedicate this humble effort to
my affectionate parents,
my elder brother Zahid Zulfiqar,
uncle Ijaz-ul-Hassnain,
aunt Bushra Ahmad and
my beloved friends.

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ABSTRACT

The knowledge of supply response greatly helps in farm decisions in allocation of resources in right direction. It can help planners and policy makers to allocate and achieve production targets and in long term planning. It thus provides a framework for adjusting production to the optimum resource employment to promote economic development. The study of supply response at disaggregated level is imperative as responses may be different for different agro-ecological zones of Pakistan. Therefore, the concern of this thesis was to examine the impact of different factors on the supply of agricultural commodities in different agro-ecological zones in Punjab in order to make necessary adjustments in the policy reforms. This study was carried out to estimate the wheat yield response function. The explanatory variables were economic, location and climatic variables. The proxy variable for economic variable was input change, for location variable it was area change and for climatic variables these were temperature and rainfall. Time trend variable was used to capture the affect of technological advances and improved farm management practices. Time series data on these variables was collected from secondary sources for the period 1979-2009. Mixed and cotton-wheat zone of Punjab were selected for the analysis and Faisalabad and Bahawalpur were selected from the above two zones respectively, mainly because of their major share in production of wheat. Dummy variable test and F-test results showed that data pooling was appropriate, so data from the two districts was pooled and used as a single entity. Then method of Ordinary Least Square was used to draw the wheat yield response function.

The effect of climatic variables was found significantly higher than that of non-climatic variables i.e., economic and location variables. The largest impact was of mean maximum average temperature at the time of maturity, ceteris paribus with one ^{o}C in its increase the average wheat yield increases by 1.4 mounds per hectare. It was concluded from the economic variable results that the level of input use was less than optimum. The location variables suggest that increasing the area virtually decreases the yield. Vertical expansion was found to be the solution of Pakistan's growing food security needs. Horizontal expansion will result in further decline in the productivity of wheat. The recommendations from this research study were that there should be timely availability of inputs, provision of adequate finance to ensure optimal input use and creating awareness among farming community about the benefits from using recommended package of inputs. There will be growing need of developing new wheat varieties which should be more adaptable to changing climatic conditions.

Keywords: Yield Response, Wheat, OLS, Pakistan

CHAPTER-1

INTRODUCTION

Pakistan is predominantly an agricultural country. Agriculture was the dominant sector of the economy at the time of independence in 1947, contributing over 53 percent to the domestic product. The importance of agriculture can be well recognized by the fact that it currently contributes 21.8% to national Gross Domestic Production. About 44.7% of the labor force is engaged in agriculture and only 12% in the manufacturing sector of the economy. Agriculture contributed 50.1% to real GDP growth rate in 2008-09. It is the major source of foreign exchange earnings, about 64% of exports are based on agriculture raw material. It is also main source of food for the rapid growing population of our country. Recent estimates indicate that about 24.033 million tons wheat, 6.9 million tons rice and 3.6 million tons of maize were being produced in the country in 2008-09 (GOP, 2010). Pakistan Agriculture has made a long and difficult journey since 1947.

Historically, during the first plan period (1955-60), the real growth rate of the agriculture sector was only 1.7 percent as against growth rates of 7.72 and 3.53 percent of industry and service sectors of economy respectively. This was due to neglect of agriculture sector and development of industry and services sectors on priority basis. The terms of trade turned against agriculture and in favor of industry through a biased protective structure and an over-valued exchange rate. This affected the agricultural exports adversely.

During the second plan period (1960-70) the institutional changes brought about in the plan period began to exert a positive influence. New high yielding varieties of wheat and rice developed at CIMMYT, Mexico and IRRI, in the Philippines were made available to farmers. These measures coupled with the increased use of water and availability of subsidized chemical fertilizers increased both the yield and production of major crops drastically. These phenomenal changes dubbed the '"Green Revolution", not only generated high rates of return to agricultural investments but also helped to achieve active growth rates beyond expectations. During this period agriculture sector grew at an extraordinary rate 5.1 percent. The other sectors of economy also flourished during this period. This accelerated the growth rate of the entire economy to 6.8 percent.

The third plan period (1970-75) however, witnessed low growth rate and a sluggish performance of agriculture sector. Several exogenous shocks to the agricultural economy contributed to this situation. These included three major droughts in 1970-71, 1971-72, 1975-75, one major flood (1973-74), the OPEC oil price hike and the consequent 300 per cent increase in fertilizer prices, the Tarbela mishap of 1974-75 and the extremely disturbed political and social conditions through most of the early seventies. Resultantly, agriculture sector grew at an average growth rate of only 2.4 percent during this period. This was the lean period for both agriculture and other sectors of the economy. This lowered the real growth rate of the economy to 4.8 percent.

From 1970 onwards, certain measures were taken by the government for the improvement of agriculture sector. A national agriculture policy was announced in 1980 and agricultural development programmes were used to be formulated in its context Agricultural Prices Commission was also set up in 1981 to fix support prices of major crops in order to provide fair returns to producers. These measures together with shifting of trade of inputs towards the private sector and other research and extension programmes led to new buoyancy in agriculture sector as shown in the Table 1.1.

Table 1.1: Average real growth rates in gross domestic product (GDP) (Percent)

Sector	1950-51 to 1959-60	1960-61 to 1969-70	1970-71 to 1979-80	1980-81 to 1989-90	1990-91 to 1999-0	2000-01 to 2009-10
GDP (fc)	3.1	6.8	4.8	6. 1	4.6	4.91
Agriculture	1.7	5.1	2.4	5.4	4.4	3.2
Industry	7.7	9.9	5.5	8.2	4.8	7.36
Services	3.5	6.7	63	6.6	4.6	5.7

Source: GOP, 2010

Not withstanding the reduction of share of agriculture sector in real GDP to 21.8 percent, this is still the single largest sector of Pakistan economy. Nearly one-fifth of total output (GDP) is generated in agriculture. It contributes substantially to Pakistan's exports. It also contributes to growth as a supplier of raw materials to industry as well as market for industrial products. Not only that country's work force is employed in agriculture but also 64.7 percent of country's population living in rural areas is directly or indirectly linked for their livelihood with agriculture. In view of its strategic importance, whatever is happened to agriculture is bound to affect not only the country's growth performance but also to the welfare of a large segment of the country's population as well.

Major problem of agriculture revolves around supply functions and relationship of product output to factor inputs. Supply response is an important production and is being used as a tool by agricultural economists to evaluate the effectiveness of policies in farmer's resource allocation. The study of agricultural supply response has received a great deal of emphasis in recent years and will continue to be an important agenda for the researchers in the future. The degree of responsiveness of farmers to economic incentives determines to a large extent the contribution that the agriculture sector makes toward the national economy. The price policies have long been the basis of farm decisions in many less developing countries. Besides prices, there are various other non-price factors such as weather, irrigation, technology etc that too influence supply (Mamingi, 1996).

The knowledge of supply greatly helps in farm decisions in allocation of resources in right direction. It can help planners and policy makers to allocate and achieve production targets and in long term planning. It thus provides a framework for adjusting production to the optimum resource employment to promote economic development. The supply response equations can be used to forecast the agricultural supplies in the future. This requires regular agricultural supply response analysis from time to time to improve the reliability of supply parameters, which are the foundations of agricultural policy.

Pakistan has two main growing seasons i.e. *Kharif* and *Rabi*. *Kharif* crops are sown during April to June and harvested from October to December. While *Rabi* crops are sown from October to December and harvested during April to June. The major crops in Pakistan include wheat, rice, cotton and sugarcane. The value added of major crops accounts for 32.8 percent of the value added in the overall agriculture (GOP, 2010).

Within agriculture wheat is the most important crop that serves as staple food for 1/3rd of the world population as noted by Agri. Marketing Round up in March 2010. Wheat is the main *Rabi* crop grown in Pakistan and being the staple diet of people occupies a central position in agricultural policies. It was grown over an area of approximately 9 million hectares last year. It accounts for 38% of the cropped area and contributes 13.1 percent to the value added in agriculture. Wheat alone accounted for 2.8% of GDP growth in 2008-09. Wheat was cultivated on an area of 9.046 million hectares in the same period, showing an increase of 5.9 percent over last year's area of 8550 thousand hectares. The size of wheat crop for the above year was 24.033 million tons, 11.7 percent more than last year crop. Due to rising population and low production in the country, Pakistan was the net importer of wheat from 1988-89 to 1999-00 and in few years ahead too. The Wheat imports in Pakistan were 1.587, 1.368 and 1.708 million tones during 1999-00, 2004-05 and 2007-08 respectively (GOP, 2009). Wheat accounted for 3.3 percent in overall imports in 2008-09. Pakistan contributes 3.5 percent to the overall world wheat production. Looking at the world situation according to international grain council, in 2009-10, world wheat production is estimated to be 675 million tons while its consumption will be around 644 million tons and its trade is predicted nearly 121 million tons. The world reserves for wheat will be 197 million tons.

Pakistan ranks 6th in terms of wheat production, 8th in terms of area but 59th in terms of yield. Netherlands had a wheat yield, in 2007-08, of 90.29 monds/acre, Belgium 86.46 monds/acre, UK 85.66 monds/acre, Germany 83.65 monds/acre, Egypt 67.24 monds/acre, the top wheat producer in terms of production China, in 2007-08, 49.25 monds/acre, USA 31.21 monds/acre, India 29.98 monds/acre while Pakistan had just 25.35 monds/acre noted by FAO. It is evident that wheat yield is too low in Pakistan as compared to the rest of world. This is indicative of the vast potential which is missed, and not realized. Also substantial gap between the yields obtained by the progressive and the average farmers supports the belief that given good management practices yields could be increased substantially. Harnessing this yield potential can go a long way in sustaining a much higher output of wheat.

Wheat is the food security crop. Despite all above Pakistan is listed by the United Nations as one of 40 countries most affected by the food crisis. As quoted above wheat is the most important staple food in Pakistan and accounts for over 55% of total caloric consumption – and this share is significantly higher for the poorest households (Jansen and Malik, 2010). Based on the balance sheet method, annual average per capita availability of wheat for human consumption during the three years from 1997-98 to 1999-00 has averaged at 137 kgs while in the previous 8 years it has declined drastically to 118.87 kgs per capita from 2000-01 to 2007-08. On this basis, gross domestic requirements (inclusive of seed, feed and wastage) for 2008-09 wheat year work out to 25 million tones. So, in order to avoid acute shortages of the staple food, wheat, the correct estimation of its availability is of utmost importance so that appropriate measures can be taken, such as taking decision about imports.

The supply projections of an agricultural commodity especially wheat plays a vital role in the adjustments of supply and demand in the future. These projections help the government to make policies with regard to relative price structure, production and consumption and also to establish relations with other countries of the world (Iqbal *et al.* 2005).

In the context of the kind of importance wheat has got as explained above the estimation of its supply response was of utmost importance, which is done in this thesis. The thesis is on estimating the supply response functions of wheat in two agro-climatic zones of Punjab, because Punjab, currently, alone contributes approximately 76.64% to the total wheat production and area. Sindh, NWFP and Balochistan respectively produce 14.73, 5.01% and 3.61% of the total output. So Punjab was selected for analysis due to its major share in wheat production and area.

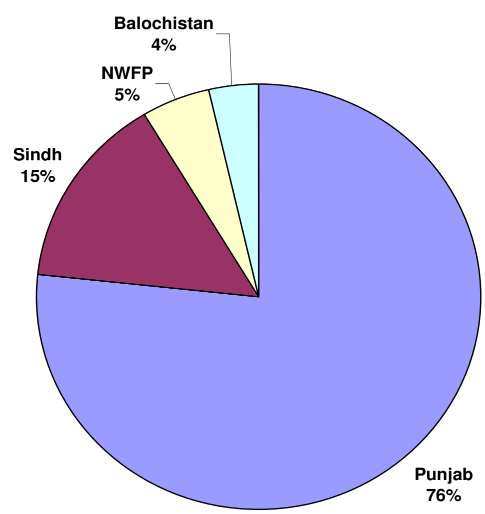

Figure 1.1: Provincial share in production during 2008-09

Wheat crop occupies 38.9 percent of total cropped area of Punjab (GOP, 2010). The area of wheat in Punjab increased from 2.90 to 6.09 million hectares during 1947-48 to 2008-09, showing an annual average growth rate of 1.35 percent. The wheat production also increased from 2.64 to 15.6 million tonnes over the period.

In Punjab usually there are four cropping zones, which produce wheat. Cotton zone is the main contributor of wheat supplies. Its share to wheat acreage and production in Punjab is 45 and 47 percent respectively. The share of mixed, rice and barani zones are 21 and 21.4, 27 and 28, and 7 and 3.6 percent respectively (GOP, 2003).

Historically, after the mid 1960s, with the introduction of new high yielding and disease resistant varieties, wheat production in Punjab increased dramatically, mainly as a result of yield increase. The average yield in Punjab increased from 848 to 2423 kgs per hectare during 1947-48 to 2007-08. This remarkable achievement in yield resulted due to incentive prices offered through Governmental price support policy, development and improvement in wheat breeding and evolution of high yielding and disease resistant varieties, adoption of seed of improved varieties by the farmers, increase in the off-take of fertilizer, better extension services and quality control of weedicides etc. Improved wheat seed distribution In Punjab increased from 94.46 thousand tons in 1999-00 to 185.15 thousand tons during 2007-08. The fertilizer consumption of N, P and K in Punjab increased from 227.18, 35.3 and 0.4 thousand tons in 1971-72 to 2618, 791 and 17 thousand tons during 2009-10 (AARI, 2004 and GOP, 2010). Although a breakthrough has been achieved in yield but our dream of self sufficiency is still fragile. There exists a wider gap between provincial average yield and potential yield. The average yield of irrigated wheat in Punjab during 2007-08 was about 26.11 mounds per acre (GOP, 2009), while potential yield of wheat is around 70 mounds per acre. This yield gap needs to be bridged which is a safe course of self-sufficiency in wheat. This requires improvement in production technology, strengthening of breeding programme, adequate and timely availability of fertilizers of all kinds and at reasonable prices, irrigation supplies at all stages of crop development and strengthening/ streamlining of agriculture policies and price structure would go a long way in Wheat autarky in the country.

The wheat market in Pakistan has mostly been subject to widely varying forms of governmental interventions, ranging from monopoly purchases in early years to support price since 1981. However, the support price has hardly been offering the farmers an economic profit on their hard labor (Khan *et al.*, 2003). This requires a well organized and farmer friendly wheat policy.

The Government of Pakistan seems to be concerned about price instability for major commodities and continues to announce "indicator prices" which are backed up in the case of wheat and to some extent cotton, through public procurement. Government of Pakistan has initiated a series of policy reforms for improving agricultural productivity and to raise farm incomes. The fixation of incentive prices and liberalization of agricultural input markets are some of policy options used by the government. The extent to which farmers respond to these policy reforms is a matter of concern to policy makers and planners. Several studies have been carried out in Pakistan in the past using OLS approach and aggregate data. Mushtaq and Dawson (2003) however, used the recent developed econometric technique of cointegration and error correction to study the supply response of major crops on aggregate data for Pakistan. The study of supply response at however, at disaggregated level is imperative as responses may be different for different zones. Therefore, the concern of this thesis is to examine the impact different factors on the supply of agricultural commodities in different agro-ecological zones in Punjab in order to make necessary adjustments in the policy reforms.

1.1 Overview of Agriculture in Punjab

Following is an overview of the agriculture sector in Punjab. In this section population, area, land utilization pattern in Punjab and in different agro-ecological zones and cropping pattern is discussed.

1.1.1 Population and Area

The Punjab province is scattered over an area of 2,05,345 square kilometers. It occupies 25.8 percent of total area of Pakistan. There are 35 districts, 131 tehsils/ taluka, 25914 mouzas/ villages and 3464 union councils in Punjab (Punjab Development Statistics 2009). The land area and population of Pakistan is unevenly distributed over its four provinces. Punjab has 25.8 and 54.71 percent of total land and population of Pakistan respectively. It is the most populous province. The population of Punjab increased from 2.05 to 7.36 millions from 1951 to 1998 at an average annual grow1h rate of 2.75 percent. The population density increased from 124 to 358 persons per square meter during the same period showing an average annual growth rate of 2.28 percent (GOP, 2003). The continuous increase in population in Punjab is creating food security issues and other civic problems.

The land area and population of Punjab is unevenly distributed among its different agro-ecological zones. Cotton zone had 51.0 percent of land area and 35.3 percent of population of Punjab. While the rice, mixed and barani zones had 22.0 and 20.7, 16.0 and 35.1, and 11.0 and 8.9 percent of land area and population of Punjab respectively.

1.1.2 Land Utilization in Punjab

The geographical area of Punjab is 20.53 million hectares. Punjab occupies 25.9 and 30.9 percent of physical and reported area of Pakistan respectively. The cultivated and uncultivated area is 57.2 and 14.4 percent respectively. The net sown area is 70.8 percent, while irrigated and cropped areas are 71.7 and 72.7 percent of Pakistan respectively. This situation reveals the importance of Punjab in Pakistan agriculture.

Land statistics in Punjab has witnessed significant changes during the period 1947 to 2007. The reported area increased from 16.78 to 17.68 million hectares. The cultivated area and net sown area increased from 8.88 to 12.60 and 7.40 to 11.04 million hectares respectively. The cropped area surged from 7.93 to 17.09 million hectares. The area sown more than once also increased from 0.05 to 6.05 million hectares (GOP, 2009). This occurred due to large investment in land and water development. The scope for future land development lies in cultivating the current fallow land, bringing culturable waste area under cultivation and increasing double cropping with the help of additional water supplies by construction of more reservoirs, water management and land improvement programmes.

1.1.3 Land Utilization in Agro-ecological Zones in Punjab

There is uneven pattern of land utilization in different ecological zones in Punjab. The distribution of land area in cotton, rice, mixed and barani zones of Punjab is as follows. The zone wise reported area is 42.7, 19.0, 25.2 and 13.1 percent of reported area of Punjab respectively. The cultivated area is 41.5, 21.7, 28.3 and 8.4 percent respectively. The cropped area is 43.7, 25.6, 25.5 and 4.9 percent respectively. The *Kharif* cropped area is 46.7, 26.8, 21.8 and 4.7 percent, while the *Rabi* cropped area is spread over 41.1, 25.0, 28.7 and 5.2

percent in respective zones in Punjab. The above situation explains the position of each zone in Punjab agriculture.

1.1.4 Cropping Pattern in Punjab

Figure 1.2 shows the cropping pattern of major crops wheat, rice, cotton and sugarcane in Punjab. As is clear from the Figure 1.2, wheat crop constitutes 38.9 percent of total cropped area in Punjab, followed by 10.5, 14.7 and 5 percent by cotton, rice and sugarcane crops respectively.

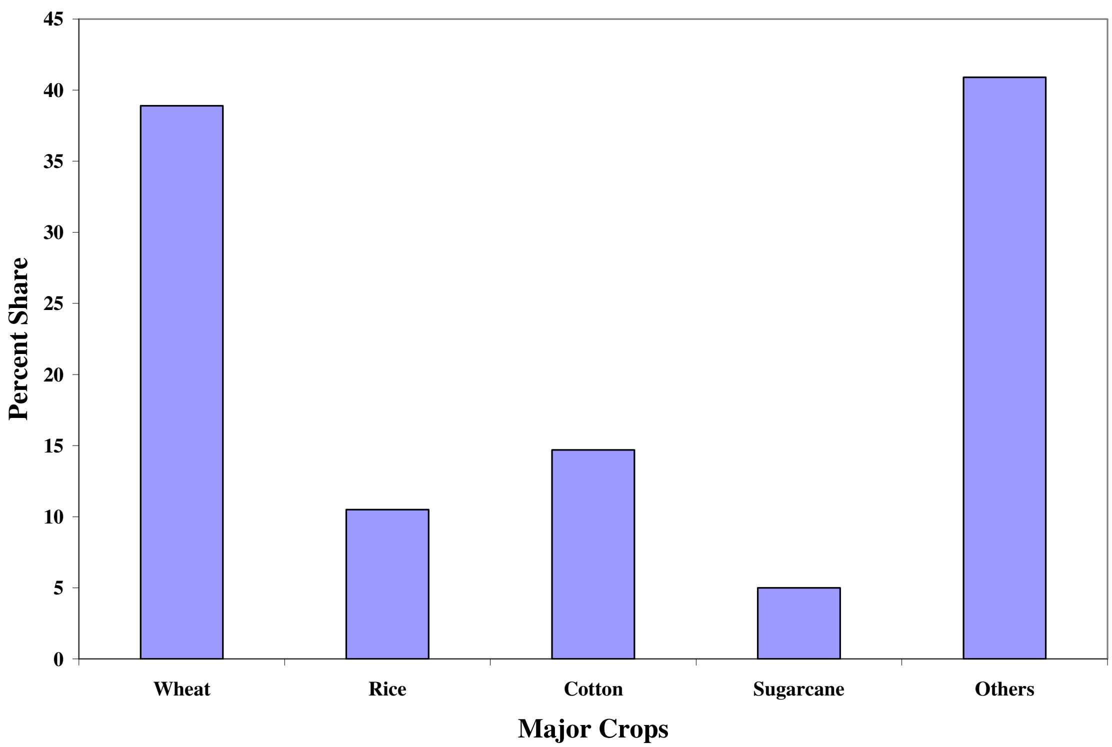

Figure1.2: Cropping pattern of major crops in Punjab

1.2 Climate/ Weather in Punjab

Climate is a key factor in agricultural production. Rainfall, temperature, humidity etc affect the production of crops at different stages.

1.2.1 Rainfall

Rainfall is an important factor which affects the acreage and yield of crops. Rain-fed barani zone has the highest quantity of rainfall, followed by rice zone, mixed zone and cotton zone respectively. Rainfall fluctuated between 697 to 1401 millimeters, 491 to 1403 millimeters, 219.5 to 718 millimeters and 72.8 to 462.5 millimeters in barani, rice, mixed and cotton zones respectively over the period 1970-2001.

1.2.2 Temperature

Temperature is another key factor affecting the production of different crops. The minimum and maximum temperature affects the crop size at different stages of crop production. The mean of minimum temperature indicated erratic trend in all the zones in Punjab over the period 1970-2001. It fluctuated between 17.3 to 19.2, 17.0 to 19.7, 15.0 to 18.2 and 14.2 to 16.6 degree centigrade in cotton, rice, mixed and barani zones respectively. The overall average minimum temperature in Punjab was recorded in the range of 16.3 to 18.2 degree centigrade over the same period (GOP, 1970-2003).

The mean of maximum temperatures ranged from 30.5 to 33.6, 28.6 to 32.3, 28.6 to 31.9 and 27.9 to 30.9 degree centigrade in cotton, mixed, rice and barani zones respectively. The overall average maximum temperature in Punjab was recorded from 29.3 to 3 1.9 degree centigrade over the same period (GOP, 1970-2003).

1.3 Plan of the Study

The study of supply response at disaggregated level is imperative as responses may be different for different zones. Therefore, the concern of this thesis is to examine the impact different factors on the supply of agricultural commodities in different agro-ecological zones in Punjab in order to make necessary adjustments in the policy reforms. Faisalabad and Bahawalpur districts were selected for analysis because they account for largest share in the total area of the Punjab in terms of wheat area. Faisalabad covers 4.15 percent while Bahawalpur covers 4.33 percent of the total wheat area, both are larger than all districts from Punjab.

Different variable are involved in the estimation of supply response function of wheat including economic, location and climate variables. The most important economic variables are the input and output prices for wheat. The prices of wheat vary affecting the farmers decision of how much to produce and how to produce as well. Wheat prices, in Faisalabad, for the month of March 2010 were Rs. 1064 per 40kg showing an increase of 21.06% over previous year prices at the same time. While in Bahawalpur wheat prices for the month of March 2010 were Rs. 1039 per 40kg showing an increase of 15.10% over previous year prices at the same time. Over all, in Punjab, an increase of 16.44% in March 2010 prices and March 2009 prices was observed[1].

With the increase in wheat prices farmers use more of inputs to increase production, while with the increase of input prices less of it is used resulting in lower productivity. The prices of inputs do vary influencing the level of their use. The cost of production of wheat has increased by above 5% from 2008-09 to 2009-10. Analyzing the prices of urea, in 2009-10, one can easily observe its price change of 23% over previous year prices in the wheat growing season[2]. Among other important inputs diesel prices have also surged during the previous year. The following graph clearly depicts an increase in its prices over time.

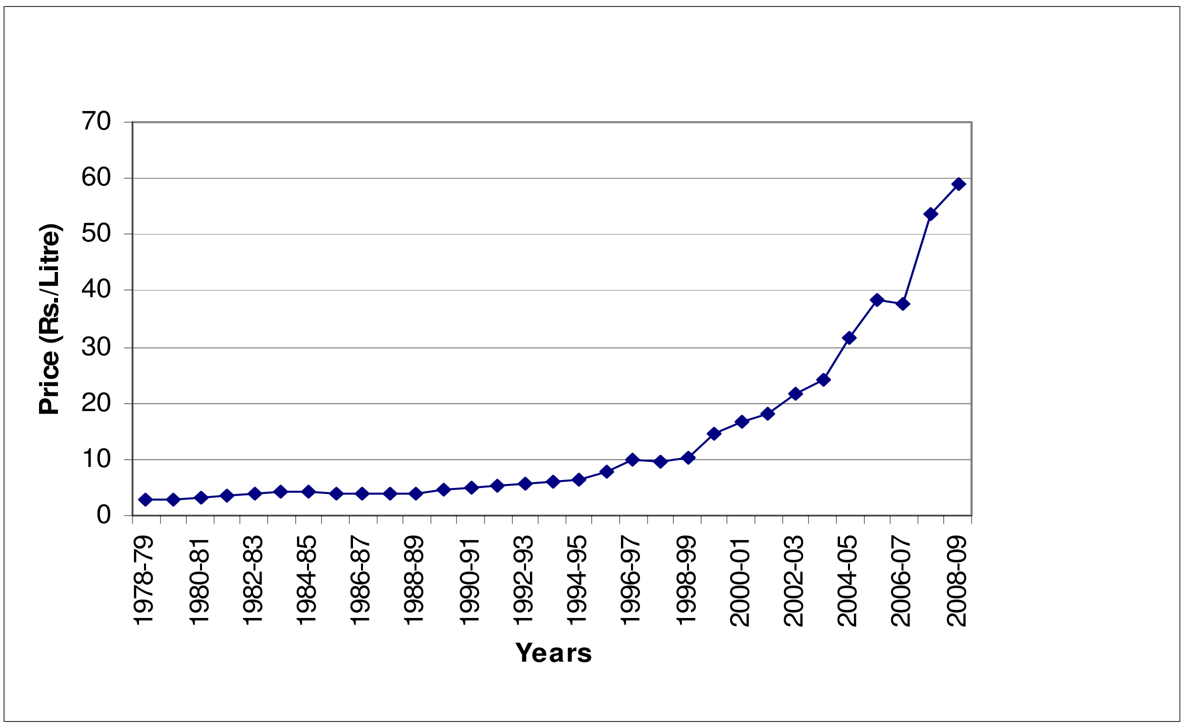

Figure 1.3: Annual prices of high speed diesel

[1] Agri Marketing Round up Page 5, March 2010, Agriculture Marketing Govt. of Punjab
[2] http://www.amis.pk/Costofproduction/2009-2010/wheat.aspx

Similarly there are various location factors involved. This fact is evident from different production levels of various districts within Punjab. Faisalabad is located in central Punjab and here the temperature and rainfall pattern is different from rest of the districts. Similarly, Bahawalpur is in southern Punjab and here average temperature is higher than that of Faisalabad having important consequences on yield of different crops in various ways, specifically on wheat yield.

Now, with the likely change in the growing conditions of different regions including Asia, Pakistani agriculture is expected to have some important consequences related to it. While the voices about climatic change are getting more and more pronounced it is becoming extremely important to foresee the likely impact it will have on our main livelihood source namely, agriculture. Climate change could have significant impact on agriculture but the first step in assessing potential costs and adaptation strategies is to determine the size and nature of these impacts on crop yields.

Important climatic variables include temperature and rainfall across regions and overtime. It varies not only in the same region but also among different regions significantly. Looking at our selected districts, Faisalabad and Bahawalpur, the above becomes clear. Rainfall is more in Faisalabad than in Bahawalpur. In Faisalabad the annual average rainfall from 1979-80 to 2007-08 stood at 31.20 millimeters while in Bahawalpur it is 13.90 millimeters in the same period. This shows marked variability in the climatic conditions of two districts overtime.

Temperature is also an important variable to consider. It specially affects the crop germination stage. Germination may occur between 4°C and 37°C, optimal temperature being from 12°C to 25°C (Spilde, 1989). The divergence of temperature from these critical limits may have strong consequences for wheat yield.

One needs to control for the various other factors and variables which affect crop yield including economic, location as well as climatic variables. The variability of crop yield in response to these variables makes agriculture one of the most vulnerable enterprises to invest in. But this high risk is also covered by high returns in the same.

1.4 Problem Statement

In an environment of fluctuating yields due to weather uncertainties and varying market responses of farmers as a whole the importance of having correct estimates of production is of utmost importance from a public policy point of view. For making right decisions about the most sensitive area of food security and for long term planning it is desirable to estimate the key variables in advance for a reasonable planning horizon.

1.5 Objectives

1. To estimate the effects of weather and climate variability on average yield and the variance of wheat yield in two different ecological zones of Punjab.
2. To compare and contrast the yield responses of farmers in the selected zones of Punjab province.
3. To suggest policy recommendations for wheat policy on the basis of estimated wheat yield response function.

CHAPTER-2

REVIEW OF LITERATURE

The purpose of this chapter is to review the literature on agricultural supply response.

Krishna (1963) studied acreage response for major crops including wheat, cotton, rice and sugarcane of the Punjab region using the time series data for 1914 to 1945-46. Ordinary Least Square (OLS) was used to estimate the single - equation supply model for each crop. The author estimated the elasticities for different crops separately for irrigated and un-irrigated areas. In case of irrigated wheat, the acreage was relatively unresponsive to relative prices and the estimated short-run and' long-run elasticities were 0.08 and 0.14 respectively. For un-irrigated wheat, the acreage was highly responsive to rainfall and the long-run elasticity was 0.22. The acreage of American cotton was highly responsive both to its relative price and the total irrigation capacity. The short- and long-run price elasticities were 0.72 and 1.62 respectively. For local varieties of cotton, relative yield was an important explanatory variable besides relative price and the short-run and long run price elasticities were 0.59 and 1.08 respectively. The sugarcane area planted in year t was influenced more by the price in year t-2 than the price in year t-1, and the short- and long-run price elasticities were 0.34 and 0.60 in year t -2 and 0.17 and 0.30 in year t-l. For rice, relative yield was an important explanatory variable in area equation besides the relative price and the short-run and long-run price elasticities were 0.31 and 0.59 respectively. The long-run elasticities were greater than those in the short-run. The short and long-run elasticities for all crops were inelastic. Krishna concluded that the farmers in Punjab respond rationally to the economic incentives. The researcher however, studied the acreage response of crops and ignored the yield response analysis which is equally important in determining agricultural supplies.

Ayub *et al.* (1974) found that deviation of rainfall from normal levels was the most appropriate rainfall variable for wheat production in irrigated areas of Pakistan. This study, along with another study by Griffiths *et al*. (1999), concluded that the choice between actual rainfall and the deviations from normal rainfall was a matter for empirical investigation and the results were not robust. But the results were at aggregate level. In my study the analysis at disaggregated level will have important policy implications.

Knight *et al*. (1978) assessed the potential for wheat production in various regions of Alaska on the basis of air temperature They believed production would be favored in regions where the mean maximum air temperature during July was at least 22°C (east-central Alaska) and would be poor in regions where the maximum July air temperature was less than 19°C (coastal and northern Alaska).

Major *et al.* (1988) found that soil moisture and nitrogen availability and location are the main factors influencing winter wheat yields on the Great Plains. A study was conducted in 1985 and 1986 at five locations with three soil water levels and four nitrogen levels to investigate yield and yield components of winter wheat. Potential yields increased with latitude but rain fed yields were similar at all sites, confirming that moisture stress is the most limiting factor on the Great Plains. Kernels per spike increased with latitude. Optimum fertility rate was about 160 kg of N ha^{-1}. Kernel weight decreased and spike numbers increased as nitrogen was increased. Increased yields from irrigation came mainly through an increased number of spikes. The three components of yield, spike number, kernels per spike and kernel weight, were significantly and positively related to yield but kernel weight and spike number appeared to be the main determinants of final grain yield.

Chaudhry and Chaudhry (1990) conducted their study to develop yield response functions of sugarcane in the Punjab province in order to identify the variables which have an influence on crop yield. They selected three cities, Faisalabad, Gujranwala and Multan districts, each representing a different ecological zone of the Punjab. They concluded that the overall increasing yield trend in Multan and Gujranwala is related to the fact that rainfall at vegetative growth period has had a significant positive effect on crop yield over the period of study. Other important variables that found to be influencing the sugarcane yield were unfavorable fertilizer crop price ratio and rainfall at the maturing and vegetative growth periods.

Chaurasia *et al.* (1991) studied that the adoption of improved varieties of seed and better farming techniques resulted continuous increase in the wheat yield in the district Ludhiana. It had almost tripled in a span of thirty years (1961-1990). The average yield in three decades viz., 1961-70, 1971-80 and 1981-90 was respectively 2.22, 3.16 and 3.74 tons per hectare. In comparison to first decade, percent increase in the average yield in second and third decade was 42 and 70 percent respectively. Increase in yield in 1st, 2nd and 3rd decades were respectively 182, 29 and 109 kg/ha per year. The month of March during the first decade was extremely warm and dry (Tx 30.9°C, H 53) and night was comparatively humid and cooler both during day and night (Tx 25.1°C, Tn 10°C) thereby increasing grain filing period and yield. During three decades the highest yield 3.14, 3.45 and 4.30 tons per hectare were observed respectively in the year 1968, 1979 and 1989. However, during 1989, the climatic conditions appeared most congenial for high yield. In this year day and night temperatures were 26.2° and 11.5°C respectively, relative humidity 68 percent and sunshine greater than 8 hours. These conditions were favorable for higher photo synthetic activity and better grain formation. The lowest yields were observed in the years having one or more factors unfavorable. The day temperature in the range of 25°C – 27°C and night temperature 11-12°C resulted in higher yield. They also studied that the grain yield had high correlation individually with maximum and minimum temperature, relative humidity and sunshine for the month of March. All the parameters except maximum temperature had positive correlation and contributed to yield. The maximum temperature had negative effect on yield.

Choi and Helmberger (1993) conducted a research study with primary objective to investigate the sensitivity of corn, wheat, and soybean yields to price changes using time series for 1964-1988. An important secondary objective was to assess the yield effects of acreage idled under farm programs. Their research strategy was based on a simple recursive model that involved two stages. The first centered on the demands for fertilizer use per acre planted; the second centered on the effects of fertilizer applications on crop yields. Corn, wheat, and soybean yields likely responded positively to increases in expected output prices but the effects appear to be very small. The estimated yield-output price elasticity was close to zero for wheat and less than 0.13 for soybeans. They held that corn yields were almost certainly increased by increases in expected corn prices and the yield-price elasticity was less than 0.27. Their estimated elasticity of demand for fertilizer per acre with respect to expected output price equaled 0.47, 0.10, and 0.82 for corn, wheat, and soybeans. Upper estimates of the elasticity of yield with respect to fertilizer equaled +0.58, +0.29, and +0.16 for corn, wheat, and soybeans. Yields were found to be quite insensitive to price changes. Fertilizer demands and yields were insensitive to land idled under farm programs.

Ismail (1993) conducted this study with primary aim of developing a supply function of wheat yield for different water application rates. The secondary objective was to determine the point of maximum yield and the optimum water application. The research study included experimenting in the fields of King Saud University for two growing seasons, 1989 and 1990. The supply function was estimated using the SAS software (SAS, 1982). The supply function was found to be both linear at low level of water application rates and nonlinear at higher water application rates. The supply function estimated was linear with the increase in applied water up to a 500 mm. Above 500 mm the relationship was curvilinear with the point of maximum yield at 734 mm. The optimum amount of applied water, after considering the cost scenario, was found to be 710 mm. While the actual water used on wheat crops grown in the study area range between 800-1100 mm, which is almost double the calculated yield. He concluded that if the present average applied water of 950 mm were decreased to optimum 710 mm level the irrigation water amounting 2400 m^3 would be saved for every irrigated hectare. Following these figures the experiment was carried out to study the response of wheat yields to applied water levels. He also explained the reason for the over utilization of irrigation water by using his model. According to the model results, he found that the wheat crop was not immediately sensitive to water application levels above the yield maximizing level because the yields did not respond negatively to water application amount greater than the yield maximizing level, in the research area. It should be observed here that due to primary nature of the experiment the problem of developing wheat production function is that it is site specific which means that the reaction found for this particular site could not be applied to another site due to different climatic and soil conditions.

Mitchell *et al*. (1993) found that many important grain crops, such as field corn, wheat, and oats tended to had lower yields when summer temperatures increased because the plant developmental cycle was speeded up and the duration of the grain-filling period was reduced. Some important crops in the North East of America, such as winter wheat, and tree fruit crops such as apples and grapes, had winter chilling, or "vernalization", requirements. These requirements usually involved a prolonged winter period where temperatures did not exceed a certain threshold temperature (e.g., 30 consecutive days with temperatures below 40 F). Warmer winters and/or an increase in winter "thaws" had negative consequences for spring flowering and yield of these crops, whether or not spring and summer temperatures were optimum for their growth.

Kaufmann and Snell (1997) estimated a hybrid regression model integrating physical and social determinants of corn yield in a way that is consistent with crop physiology and economic behavior. They found that climatic variables account for 19% of the variation in corn yield for counties in the US Midwest while social variables accounted for 74% of the variation.

Wassenaar *et al.* (1999) presented a study on the impact of soil and climatic variability on the yield of winter wheat in the Hérault-Libron-Orb Valley in southern France. The study was based on the use of a crop simulation model (Euro-ACCESS), run at 63 individual sites throughout the study area, for the climate (1976 to 1984) and for potential future changes in temperature and precipitation (2047 to 2054). Three climate scenarios were selected to represent low, mid and high changes, although significant winter wheat yield decreases were only observed for the climate scenario with the largest change. Three rainfall stations, Béziers, Pézenas and Aniane, were selected. The 26 soil profiles were combined with the 3 selected climate stations to obtain 78 theoretical soil-climate situations, which represent the range of soil-climate spatial variation observed within the region. In general, the influence of climate change on yields was found small (less than 0.1 t ha^{-1} over the whole simulation period), but strong inter-annual variation was found, which is well known only for typical of the Mediterranean climate. They analyzed that the relationship between successive years remained the same, but the yield change generally was shifted by at least –0.5t ha^{-1}. This resulted in an average yield decrease of around 0.8 t ha^{-1}, varying over the 8 yr period from 0 (1982 to '2052') to 1.7t ha^{-1} (1984 to '2054'). Soil variability within the study region was the most important source of spatial variability for the simulated yields, and the soil available water capacity was identified as a good indicator of yield change for large climatic change.

Kayam *et al.* (2000) studied that the reduction of 5-10% in the rainfall, in the Aegean region of Turkey had a small effects on the wheat yield in a region with 500-600mm of rainfall. The increase in temperature on the other hand by 1-2°C was reduced yields by 7.4% per 1°C. It was assumed that the combined effect of 10% reduction in rainfall and 2°C increase in temperature was greater than each separate effect.

Graciela *et al.* (2003) studied that the potential wheat yield had been declining at increasing rates since 1930 mainly due to minimum temperature increases. Further increases in temperature led to potential wheat yield reductions of 7.5% for each 1°C of temperature rise. If the expected effects of CO_2 really did occur, the decline of the potential wheat yields due to temperatures that was 2.5°C warmer was entirely offset by a CO_2 concentration of 550 ppm. If the CO_2 effects were not considered, rain fed wheat yields was reduced by 4% by the end of the 21st century (2080), the northern part of the Pampas region being the most affected zone. Inversely, if the CO_2 effects were considered, rain fed wheat yield was increased by 14%. Advancing planting dates was a good strategy to take advantage of new environmental conditions with prolonged frost-free periods.

Mushtaq and Dawson (2003) quantified and evaluated the supply (yield) response of wheat and cotton in Pakistan using cointegration analysis. Their results reveal that wheat supply is significantly influenced by the prices of wheat, cotton and fertilizer, the percentage area under high yielding wheat varieties, and the *Rabi* season (winter) water availability. But they did not included climatic variables into their analysis.

Shiluli *et al.* (2003) conducted experiments in western Kenya to determine the agronomic and economic benefits of applying Nitrogen (N) and Phosphorus (P) to maize. The experiments were conducted in 2 locations on farmers' fields in 1994, 1995 and1996. Four levels of Nitrogen (0, 30, 60, 90-Kg ha^{-1}) were combined with three levels of Phosphorus (0, 40, 80-Kg ha^{-1}) to constitute twelve treatments which were tested on a randomized complete block design. They concluded following results: statistical analyses of yield data revealed that N application consistently affected grain yield significantly in all locations. Phosphorus had a significant effect on yield once in each location. There was significant nitrogen by phosphorus interaction (N*P) effects once in each location. Analysis across sites showed N and N*P interaction to be statistically significant. The statistically significant treatments of this experiment were subjected to economic analysis using the partial budget procedure to determine rates of N: P that would give acceptable returns at low risk to farmers. Economic analysis on the interaction across location showed that two N: P combinations i.e. 30:0 and 60: 40 kg ha^{-1} are economically superior and stable within a price variability range of 20%.

Khan *et al.* (2003) studied the impact of Pakistan's support price policy on wheat production in the country. They applied the Frontier Production Program (FPP) for their analysis. They used national level data for Pakistan, on all inputs, output and prices taken from secondary sources, over the period 1966-2001. Both Ordinary Least Square (OLS) and Maximum Likelihood Estimate (MLE) methods were used. They found the following results, the MLE results show that 1 percent increase in real price increases the wheat production by about one third, 0.3388 percent, and it was highly significant. The estimated coefficient of water was also highly significant and shows that 1 percent increase in water availability increases the wheat production by 0.6838 percent. The results of this study support the findings by Ikram (2000) who also shows that wheat growers in Pakistan respond positively to the price incentives. They concluded that statistical findings of the study show that support price policy in Pakistan has positively affected the wheat production levels. However, no effect was observed on the farmers' yield.

Zhu (2004) studied that higher temperatures generally decreased yields by speeding up a plant's development so that it matured sooner, thus reduced the period available to produce yields. Higher temperatures often also exacerbated stress on water resources that are essential for crop growth, and warmer and wetter conditions also tended to affect the prevalence of pests, diseases and weeds. Climate change enabled crops to grow in places they were not currently grown and in different time periods than usual. It also reduced yields to below an economical threshold for the farmer. Further, the high frequency of natural disasters like floods and droughts associated with climate change made the situation even worse estimated that by 2030, grain production in China might decrease by up to 10 per cent because of the change in temperatures. The output of the three major crops in China - rice, wheat and maize was expected to decline. The maize planted in North China was a summer variety, and the effects of higher temperatures combined with the resulting increase in evaporation and poor irrigation due to less rainfall were expected to shorten the growing period and thus reduced overall yields. Climate change was also expected to have a more adverse impact on spring wheat than on winter wheat. Spring wheat yields were likely to decrease by about 30 percent and winter wheat by about 14 per cent by 2080.

Iqbal *et al.* (2005) aimed their study to forecast the area and production of wheat in Pakistan up to the year 2022. They used ARIMA (Auto Regressive Integrated Moving Average) model in order to meet their objectives. They used past thirty years data for this purpose. Forecasts were made from 2002 up to 2022. These projections were based on the assumptions of i) Absence of random shocks in the economy, internal or external. ii)

Agricultural price structure and polices will remain unchanged. iii) Consumer preferences will remain the same. They concluded that in order to increase yield and production selection of high yielding varieties, massive education of farmers through a net work of agriculture officers to make improvements in cultural practices, adequate supply of inputs and full scale use of latest technology are important. They found that the only way to increase the total cropped area is through reclamation and conservation of land.

You *et al.* (2005) concluded that a 1% increase in wheat growing season temperature reduced wheat yields by about 0.3%. Across wheat growing provinces in China, the growing season temperatures varied from 5 to18°C, so this meant 1.5% to 5.4% decline of wheat yield for each 1°C increase of temperature in China. This estimated effect of temperature on wheat yield was smaller than the previous three studies i.e. rice in Philippines (Peng *et al.* 2004), wheat in Australia (Nichalls 1997), corn and soybean in USA (Lobell and Asner, 2003).

Thornton *et al.* (2008) studied some possible impacts on crop yields in Africa. They used two crop models, one for main-season maize and second for secondary-season phaseolus beans, with daily weather data that are thought to be characteristic of future climatic conditions in the region, as represented by a combination of two climate models and two contrasting greenhouse gas emission scenarios. Their analysis shows that a substantial part of heterogeneity in yield response can be explained by temperature effects. In maize, at high altitudes, yields may increase as temperatures increase, but at most lower elevations, yield changes also depend on water availability, and many places will see increasing water stress in the maize crop, all other things being equal. They concluded that for secondary season beans, temperature-driven yield increases will occur at higher elevations or up to average temperatures of about 20-22 C^{o}. Beyond these temperatures, yields will tend to decline.

Cabas *et al.* (2009) in their study in southwestern Ontario, Canada examined the effects of climatic and non-climatic factors on the mean and variance of yield of corn, soybean and winter wheat for a period of 26 years. They concluded that average crop yields increase at a decreasing rate with the quantity of inputs used, and decrease with the area planted to the crop. They also found that climate variables have a major impact on mean yield and increases in the variability of temperature and precipitation decrease mean yield and increase its variance.

Carew *et al.* (2009) conducted a study with the objective to employ a Just-Pope production function to examine the relationship between fertilizer inputs, soil quality, biodiversity indicators, cultivars qualifying for Plant Breeders' Rights (PBR), and climatic conditions on the mean and variance of spring wheat yields. Wheat yield, fertilizer, proportion of wheat seeded area, and soil quality data were obtained for 15 crop insurance risk regions of Manitoba from 2000 to 2006. Just-Pope production function was employed to quantify the contribution of nitrogen fertilizer, environmental conditions, cultivar diversity, and cultivars qualifying for PBR on mean yield and variance. Using regional-level wheat data from Manitoba, Canada, model results showed nitrogen fertilizer, temporal diversity, and PBR wheat cultivars were associated with increased yield variance. Mean wheat yield was reduced by the proportion of land in wheat, the interaction of growing temperature and precipitation, and spatial diversity. By contrast, higher soil quality and PBR wheat cultivars increase mean yield. The wheat yield increases attributed to PBR range from 37.2 (1.4%) to 54.5 kg/ha (2.0%). They concluded that Plant Breeders' Rights may have enhanced royalties from increased certified seed sales, but the benefits in terms of higher wheat yield or lower yield variability were limited. They also concluded that spatial and temporal diversity had a negative effect on mean yield. Regional wheat yield was found to be lower when a higher proportion of planted land was devoted to wheat. Fertilizer typically increased wheat yield, but with regional data and producers' applying fertilizer at optimal rates, only a small yield response or inconclusive impact was evident. Cultivars protected by PBR had a small positive impact on yield in two of the three models. Wheat yield variance was higher with increased temporal diversity and with greater use of PBR cultivars. Higher quality soils were found to have less yield variability, while nitrogen fertilizer increased yield variability. There was some indication that other fertilizers, such as sulfur, either had a limited yield impact or contribute to less yield risk.

Niamatullah *et al.* (2010) attempted to measure the significant contribution of price factor (support price) and non-price factor (fertilizer off-take) towards rice production and wheat acreage responses in NWFP, Pakistan by employing Nerlovian adjustment model through ordinary least square estimation technique over a period of time (1975-76 to 2007-08). 1st aspect of findings suggested that support price had strong bearing on rice production ($P<0.05$) and fertilizer off-take had attained significant relationship with rice production

(P<0.10). They hold that the announcement of support prices had certainly strong bearing on rice production in NWFP. In view of production response of rice, the short run and long run support price elasticities as well as short and long run fertilizer off-take elasticities were found sizeable with low divergence. For support prices, the short run and long run elasticities worked out as 0.09 and 0.14, for fertilizer off-take, the short run and long run elasticities have been worked out as 0.07 and 0.11 respectively. In case of wheat acreage, the short run and long run price elasticities (support prices) were -0.002 and -0.009, while the short run and long run non-price elasticities (fertilizer off-take) were -0.03 and -1.04 respectively. 2nd aspect of findings suggest that fertilizer off-take had shown remarkable influence over wheat acreage (P<0.10). Hence the issue of nutrient deficiency was overcome due to balanced use of fertilizer off-take especially NPK had played a crucial role in achieving enhanced rice production and wheat acreage in NWFP.

All the above studies measured the impact of different variables on different crops in different parts of the world. However such work has not been done in Pakistan extensively. Therefore, the present study will estimate the impact of such different economic, location and climatic variables wheat crop, which is an important basic food crop of Pakistan.

CHAPTER-3

METHODOLOGY

A very important and significant thing in conducting any analytical study is to adopt a systematic and appropriate technique. After formulating the study and specific objectives, devising an appropriate methodology to conduct and complete the study is very important step. Data collection, various related values and trends present in any type of data (quantitative and qualitative) should carefully be applied and practiced (Akhtar, 1999).

Wheat is grown in various parts of the country and Punjab is the main supplier, supplying above 76% of wheat. So this research study is on estimation of wheat yield response under different economic, location and climatic conditions in Punjab. Punjab is divided in rice-wheat Punjab, mixed Punjab, cotton-wheat Punjab, low intensity Punjab and barani Punjab agro-ecological zones and for the purpose of current analyses two agro-ecological zones, namely mixed zone and cotton-wheat zone, were selected as representative of all wheat growing areas of Punjab. These two zones combine; contribute 68.4% to total wheat production in the country. From these Faisalabad and Bahawalpur districts were selected from mixed zone and cotton-wheat zone respectively. As discussed in previous sections these two districts were selected based on their large area and production as compared to other districts in these zones.

3.1 Model Specification

As a first step of model specification any structural difference in the regression of two districts, Faisalabad and Bahawalpur, was inquired. If there exists some structural difference in the two districts separate model should be developed for estimating the wheat yield response function. But if there would be no difference in them data can be pooled and used as a single entity.

3.2 Tests for Pooling of Data

Two tests have been used here for pooling the data. One is the dummy variable test and other is the F-test. The detail is presented below.

3.2.1 Dummy Variable Test

Dummy variable test is used for the analysis of pooling the data. Chow test is used to test that there is a difference in the regression of two districts or not. It tells the overall stability of the model using the F-test approach. However, it cannot be decided on this basis whether the difference in the two regressions is because of differences in the intercept terms or the slope coefficients or both. Very often this knowledge itself is very useful. So, dummy variable test is used here. There are four possibilities about differences in two regressions:

1. **Coincident regressions:** Both the intercept and the slope coefficients are the same in the two regressions.
2. **Parallel regressions:** Only the intercepts in the two regressions are different but the slopes are the same.
3. **Concurrent regressions:** The intercepts in the two regressions are the same but the slopes are different.
4. **Dissimilar regressions:** Both the intercept and slopes in the two regressions are different.

The multi-step Chow test procedure tells only if two (or more) regressions are different without telling what the source of the difference is. The source of difference, if any, can be pinned down by pooling all the observations and running just one multiple regression as below:

$$Y_t = \alpha_o + \beta_o D + \beta_1 X_{1t} + \beta_2 X^2_{1t} + \beta_3 X_{2t} + \beta_4 X_{1t} X_{2t} + \beta_5 (D X_{1t}) + \beta_6 (D X^2_{1t}) + \beta_7 (D X_{2t}) + \beta_8 (D X_{1t} X_{2t}) + \mu_t \quad \ldots\ldots\ldots\ldots\ldots (3.1)$$

Where;

Y= Yield

X_{1t}= Input change

X_{2t}= Area change

t= Time

D= 1 for observations from Bahawalpur

= 0, otherwise (i.e., for observations from Faisalabad)

In the above equation β_o is the differential intercept and β_5, β_6, β_7 and β_8 are the differential slope coefficients (also called slope drifter), indicating by how much the slope coefficient of the Bahawalpur function (the category that receives the dummy value of 1) differs from that of the first period. The introduction of the dummy variable D in the interaction or multiplicative form (D multiplied by X) helps in differentiating between slope coefficients of the two periods just as the introduction of the dummy variable in the additive form helped to distinguish between the intercepts of the two periods.

3.2.2 F-Test for Checking Structural Stability

In order to check any structural change in the supply response models of the two selected districts F-test has been used. This test tells, in the time series data, whether there is a structural change in the relationship between the regressand and the regressors. The structural change means that the values of the parameters of the model do not remain same in the two districts. This structural change may be due to economic factors of the region, different farming practices and access to input and output markets etc.

Time series data for Faisalabad and Bahawalpur for different economic variables from 1979-2009 relating wheat was used. The F-test uses the following methodology to identify structural change.

For the purpose of analysis there may be following possibilities of regressions:

$$Y_t = \alpha_o + \beta_o D + \beta_1 X_{1t} + \beta_2 X^2_{1t} + \beta_3 X_{2t} + \beta_4 X_{1t} X_{2t} + \beta_5 (D X_{1t}) + \beta_6 (D X^2_{1t}) + \beta_7 (D X_{2t}) + \beta_8 (D X_{1t} X_{2t}) + \mu_{1t} \text{ ……(3.2)…….Unrestricted}$$

$$Y_t = \alpha_o + \beta_1 X_{1t} + \beta_2 X^2_{1t} + \beta_3 X_{2t} + \beta_4 X_{1t} X_{2t} + \mu_{2t} \text{ ……(3.3)………. Restricted}$$

The null hypothesis here is that the regressions of Faisalabad and Bahawalpur are similar. And alternate hypothesis is that they are not.

The formula used for F_{cal} is as following:

$$F_{cal} = \frac{(RSS_R - RSS_{UR})/k}{RSS_{UR}/(n-2k)} \text{ ………. (3.4)}$$

Where; F_{cal} = F calculated

RSS_R = Residual Sum of Square Restricted

RSS_{UR} = Residual Sum of Square Unrestricted

n = Number of observations

k = Number of restrictions

If F-calculated turns out to be less than F-table the null hypothesis of similar or coincident regression is accepted and vice versa.

3.3 Multicollinearity Test

If the independent variables are collinear using the same data for estimation may give spurious results. So it is necessary to check it for having reliable estimates. There are various tests for checking the multicollinearity, the simplest of them is using Pearson correlation test, developed by Karl Pearson, for identifying correlation among independent variables. It is obtained by dividing the covariance of the two variables by the product of their standard deviations. The population correlation coefficient $\rho_{X1,X2}$ between two random variables X and Y with expected values μ_{X1} and μ_{X2} and standard deviations σ_{X1} and σ_{X2} is defined as:

$$\rho_{\mathrm{X1,X2}} = corr(X1, X2) = \frac{\operatorname{cov}(X1, X2)}{\sigma_{X1}\sigma_{X2}} = \frac{E[(X1-\mu_{X1})(X2-\mu_{X2})]}{\sigma_{X1}\sigma_{X2}} \text{...........(3.5)}$$

Where E is the expected value operator, *cov* means covariance and *corr* a widely used alternative notation for Pearson's correlation.

The Pearson correlation is defined only if both of the standard deviations are finite and both of them are non-zero and the correlation cannot exceed 1 in absolute value. The correlation coefficient is symmetric: corr(X_1, X2) = corr(X_2, $X1$). The Pearson correlation is +1 in the case of a perfect positive linear relationship, −1 in the case of a perfect negative linear relationship, and some value between −1 and 1 in all other cases, indicating the degree of linear dependence between the variables. As it approaches zero there is less of a relationship. The closer the coefficient is to either −1 or 1, the stronger the correlation between the variables. If the variables are independent, Pearson's correlation coefficient is 0, but the converse is not true because the correlation coefficient detects only linear dependencies between two variables. For example, suppose the random variable X is symmetrically distributed about zero, and $X_1 = X_2^2$. Then X_1 is completely determined by

X_2, so that X_1 and X_2 are perfectly dependent, but their correlation is zero; they are uncorrelated.

3.4 Estimation of Crop Yield Response

After checking the multicollinearity of the variables the next step is identifying key independent variables which have an affect on the dependent variable.

3.4.1 Dependent Variable

The base dependent variable for the analysis is yield in mounds per hectare for wheat. Yield data was collected from AMIS (Agriculture Marketing Information Service) for the two selected districts of Punjab.

3.4.2 Explanatory Variables

The yield response model was found to have three major categories of explanatory variables: (1) economic variables, (2) site characteristics and (3) climate variables.

Output to input price ratios were used as an economic variable to explain yield as used by Rickard and Fox (1999), Segerson and Dixon (1999), and Dixon *et al.* (1994). Actual input levels by crop are difficult to determine so input use will be measured using the approach of Kaufmann and Snell (1997). The change in input use (*Input Change*) can be determined by re-arranging the profit maximizing input level condition (as determined by Juan *et al.* (2008)) which is where marginal value product i.e., $P_{crop} * (\Delta y / \Delta Q_{input})$ is equal to the input price (P_{input})

$$Input\_change = \Delta Q_{input} = Q_{input,t} - Q_{input,t-1}$$

$$= \frac{P_{crop,t-1}(y_{crop,t} - y_{crop,t-1})}{P_{input,t}} \quad \ldots\ldots\ldots(3.6)$$

Where $Q_{input,t}$ is the quantity of purchased inputs per acre in period t, $P_{crop,t-1}$ is the price per unit of crop lagged one year, $P_{input,t}$ is the price index for input purchased in the current period, and $y_{crop,t}$ is crop yield in the current period. Crop price is proxied by actual prices in the previous year and input prices are measured by the index of prices paid by farmers. For the creation of input price index only the most important inputs were included. The input prices taken into analysis were of urea, DAP, electricity and high speed diesel (HSD). Because only the trend of the input prices was of main concern the input price index was created by simply adding the input prices of these.

Site characteristics can partially be captured by the percentage change in acres planted to a crop from one period to the next (*Area Change*). It is assumed that the effect of this area change is non-linear and that increases in area decrease yield at a decreasing rate since the quality of the marginal land planted declines with more area. The lower-quality land will also be subject to greater yield variation. A time-trend variable (*Time Trend*) is also added to represent the effect of technological progress, such as new crop varieties and improved cropping practices.

The effect of climatic variables was captured by using average temperature and rainfall in the two districts in the crop growing time period.

Least square technique had been used to estimate different regression equations for the wheat yield response function estimation in Punjab. Several forms of equations were analyzed and different models were run by using different software and finally selected the best ones among them. The analysis was done under usual assumptions. It had been hypothesized that the yield response of wheat crop was influenced by the economic, site and climatic variables.

The general production function used for the analysis was:

Wheat yield=f (economic variables, site variables, climatic variables)…….(3.7)

3.5 Yield Response to Economic and Site Variables

In this model, only the economic and site characteristics were used as independent variables and no climatic measures. Thus,

$$Y = f\,(\text{Input Change}, (\text{Input Change})^2, \text{Area Change}, (\text{Area Change})^2, (\text{Input Change})*(\text{Area Change}), \text{Time Trend}) \;\ldots\ldots\ldots.(3.8)$$

If X_1 is input level, X_2 is area of wheat, T is trend variable and Y is wheat yield then the above model can be written as

Model 1

$$Y_t = f\,(dX_1,\, dX_1^2,\, dX_2,\, dX_2^2,\, dX_1{*}dX_2,\, T)\ldots\ldots(3.9)$$

$$Yield_t = \beta_o + \beta_1\ input\_change + \beta_2\ input\_change\_sq + \beta_3\ area\_change + \beta_4\ area\_change\_sq + \beta_5\ input\_change\_area\_change + \beta_6\ time\_trend + \mu_t\ \ldots\ldots(3.10)$$

Where d represents change in each of the variable in the equation, t is showing time series observations, μ is error term and input_change_area_change is interaction of input change and area change.

In this model wheat yield was dependent on input change, input change square, area change, area change square, interaction of input change and area change and lastly time trend variable. Input change, input change square and time trend variable were found to be statistically significant at normal level (i.e. 5%) of significance i.e. significantly affect the wheat yield and other variables were turned out as statistically non-significant. Looking at the correlation between independent variables show that area change and area change square as well as area change square and interaction term were found to be highly correlated, so they cannot be used in the same model at the same time, otherwise our results will be spurious. F-test had shown that the model is appropriate while most of the variables were insignificant giving a clear indication of presence of multicollinearity in the model (the reason being very high correlation between area change and area change square). Thus this model was not used for further analysis due to insignificance of most of the variables (i.e., 3 variables out of total 6 variables) and presence of multicollinearity in the model. The results of the model 1 are as below.

Table 3.1: Results of Model 1

Variables	Coefficients	Std. Error	t-Stat	P-value
(Constant)	42.761	2.822	15.151	.000
Input_change	0.811	0.349	2.322	.024
Input_change_sq	0.210	0.054	3.870	.000
area_change	-0.035	0.186	-0.188	.852
area_change_sq	-0.001	0.008	-0.105	.917

Input_change_area_change	0.030	0.046	0.649	.519
time_trend	0.255	0.085	2.985	.004

So looking at the previous results and correlation coefficients it was important to drop some of the variables from the model which cause multicollinearity. Examining the Pearson correlation matrix it was found that area change square was highly correlated with both area change and interaction term. Thus it was considered wise to drop area change square instead of dropping two variables. Hence the following model was estimated by dropping the area change square variable.

Model 2

$$Yield = \beta_o + \beta_1\ input\_change + \beta_2\ input\_change\_sq + \beta_3\ area\_change + \beta_4 input\_change\_area\_change + \beta_5\ time\_trend + \mu_t \ldots\ldots(3.11)$$

All variables are as previously defined.

The results of the above estimated model indicate that the overall model (F-value has increased) has improved after removing the impact of highly collinear variable, area change square. Pearson correlation matrix also shows that there was not very high correlation between the independent variables. The overall fitness of the model and significance of individual variables is appropriate, so above model was used for further analysis. Climatic variables were included in this model in order to check the wheat yield response to economic, site and climatic variables. The complete results of the model analyzed are discussed in results and discussion. But firstly the impact of climatic variables was analyzed on wheat yield alone.

3.6 Yield Response to Climatic Variables

In this model wheat yield response to climatic variable was analyzed. Climatic variables included mean maximum temperature, mean minimum temperature and mean rainfall for the months of November, December, January, February, March and April. As a starting point all the above three variables were divided in three periods namely sowing, vegetation and maturity. The sowing period included months of November and December. The vegetation period included months of January, February and March whereas April was considered to be crop maturing period followed by harvesting of the crop. A general description of this model is as following.

Model 3

$$Y_t=\beta_o+\beta_1\, temp\_max\_sowing+\beta_2\, temp\_max\_vegetation+\beta_3\, temp\_max\_maturity+\beta_4\, temp\_min\_sowing+\beta_5\, temp\_min\_vegetation+\beta_6\, temp\_min\_maturity+\beta_7\, rainfall\_sowing + \beta_8\, rainfall\_vegetation+\beta_9\, rainfall\_maturity \ldots\ldots\ldots(3.12)$$

All variables are either already explained or are self explanatory.

OLS estimation of the model results in most of the variables being insignificant but overall fitness of the model satisfactory giving a clear indication of the presence of multicollinearity. Only mean minimum sowing temperature was significant at 5% level of significance. The analysis shows that with each one degree Celsius increase in the minimum temperature the predicted wheat yield increase was found 2.89 mounds per hectare. All other climatic variables were found insignificant. Most of the variables had high correlation with each other when combined in a Pearson correlation matrix. As all of the variables, except minimum sowing temperature, were insignificant this model was not used to include economic and site variables. The results of the model are following.

Table 3.2: Results of Model 3

Variables	Coefficients	Std. Error	t-Stat	P-value
(Constant)	-77.022	43.771	-1.760	.085
temp_max_sowing	-0.163	0.807	-0.202	.840
temp_max_vegetation	-0.767	2.153	-0.356	.723
temp_max_maturity	3.011	1.704	1.767	.084
temp_min_sowing	2.892	0.994	2.911	.005
temp_min_vegetation	3.268	2.055	1.590	.118
temp_min_maturity	-0.267	2.403	-0.111	.912
rainfall_sowing	0.220	0.240	0.915	.365
rainfall_vegetation	0.056	0.176	0.318	.752
rainfall_maturity	-0.110	0.133	-0.832	.410

After lengthy modeling procedure and trying a large number of models through hit and trial method, intuition and on theoretical grounds the following model was considered to be best representing the wheat yield response to climatic (environmental) variables. The general model can be written as:

Model 4

$$Y_t = \beta_o + \beta_1\, temp\_max\_maturity + \beta_2\, temp\_\, min\_sowing + \beta_3\, rainfall\_avg + \beta_4\, rainfall\_cov \ldots\ldots (3.15)$$

Where rainfall_avg is average rainfall and rainfall_cov is rainfall covariance. It is important to mention here that after detailed analysis of the data in maturity period March and April was included rather than just April. Rainfall_cov is measured as the standard deviation of the monthly precipitation estimates expressed as a percentage of the annual mean of those estimates. This variable has been included to capture the effects of extreme events on average crop yield. An increase in the covariance represents an increase in the proportionate variability of these two weather variables and it was assumed to decrease the level of crop yields.

Applying OLS technique to the above model result in significance of maximum temperature at maturity, minimum temperature at sowing and rainfall covariance while insignificance of average rainfall variable. Overall model R-square, F-test and t-test of individual coefficients prove that this model appropriately present wheat yield response to climatic variables. Thus this model was combined with the previous yield response model to economic and site variables. The detailed results are discussed in results and discussion.

3.7 Yield Response to Economic, Site and Climatic Variables

Having analyzed the separate response of economic and site variables and of climatic variables on wheat yield the next step is the estimation of wheat yield response to economic, site and climatic variables altogether.

The general model by combining equations 3.11 and 3.15 can be written as following.

Model 5

$$Y_t = \beta_o + \beta_1 input\_change + \beta_2 input\_change\_sq + \beta_3 area\_change + \beta_4 input\_change\_\, area\_change + \beta_5 time\_trend + \beta_6 temp\_max\_maturity + \beta_7\, temp\_\, min\_sowing + \beta_8\, rainfall\_avg + \beta_9\, rainfall\_cov + \mu_t \ldots\ldots (3.16)$$

The estimation of the model through OLS gives input change, input change square, time trend, max temperature at maturity and minimum temperature at sowing stage variables significant while area change, interaction of input change and area change, average rainfall and rainfall covariance insignificant. R square value was approximately 0.79 and overall model was highly significant at 1% level, predicted by F-test. But the problem in this model was that the climatic (environmental) variables were highly correlated with each other (Pearson correlation matrix). Thus they cannot be used together. The detailed results are discussed in results and discussion.

Analyzing various possibilities for combining the economic, site and climatic variables in one model and then individual analysis of the independent variables as well as overall model significance following model was considered to be best representing the wheat yield response. The general model was

Model 6

$$Y_t = \beta_o + \beta_1 input\_change + \beta_2 input\_change\_sq + \beta_3 area\_change + \beta_4 input\_change\_area\_change + \beta_5 time\_trend + \beta_6 temp\_max\_maturity + \beta_7 rainfall\_avg + \mu_t \quad \text{.......(3.17)}$$

The above model estimation by ordinary least square (OLS) resulted in 0.474 R-square value. The overall model was significant as given by the ANOVA Table, the F-value was highly significant i.e., at 1% level of significance. All of the variables had sign and size as expected and were significant. Input change, input change square, time trend, mean maximum temperature at maturity (average of March and April) and average rainfall were significant. While area change and interaction of input change and area change were insignificant.

3.8 Testing the Viability of the Model

In order to check the viability of the model Wald test was applied.

Wald Test

The **Wald test** is a parametric statistical test named after Abraham Wald with a great variety of uses. Whenever a relationship within or between data items can be expressed as a statistical model with parameters to be estimated from a sample, the Wald test can be used to test the true value of the parameter based on the sample estimate. In the Wald test the economist uses the estimate and an estimate of variability to draw conclusions about the unobserved true coefficient.

Under the Wald statistical test, the maximum likelihood estimate $\hat{\theta}$ of the parameter(s) of interest θ is compared with the proposed value θ_O, with the assumption that the difference between the two will be approximately normal. Typically the square of the difference is compared to a chi-squared distribution. In the univariate case, the Wald statistic is $\frac{(\hat{\theta} - \theta_O)}{\mathrm{var}(\hat{\theta})}$, which is compared against a chi-square distribution.

3.9 Data Sources

Secondary data from 1978 to 2007 was collected from the following data sources.

- Agriculture Marketing Department, Lahore
- Agriculture Statistics of Pakistan
- Economic Survey of Pakistan
- Punjab Development Statistics
- National Fertilizer Development Centre, Islamabad
- Regional Meteorological Department, Lahore

CHAPTER-4

RESULTS AND DISCUSSION

This chapter is divided into two parts. In the first part, the results of the tabular analysis are described and in the second part, the results of the regression analysis are discussed.

4.1 Descriptive Analysis

The descriptive analysis is divided into two parts. In the first part analysis about Faisalabad and in the second part Bahawalpur is discussed. The variables discussed are wheat area, production and yield of wheat crop in the two selected districts (Faisalabad and Bahawalpur) for the period from 1979 to 2009. Then monthly prices of wheat in the two districts and the mean monthly maximum and minimum temperature and average rainfall in the two districts and their covariance are shown.

4.1.1 Overtime Performance of Wheat Crop in Faisalabad

Looking at the area, production and yield trends helps understanding the basic idea behind the response function. It can be ascertained from these trends that whether the increase or decrease in yield overtime has been due to area changes or there exist some other factor which determine the yield level. The area, production and yield of wheat in Faisalabad district from 1979 to 2009 is given below. As is clear from the following Table 4.1 area has almost remained static in the whole study period. It increased from 267 thousand hectares to just 272.65 thousand hectares from 1979 to 2009 increasing by just 2% in 30 years while yield increased above 109% in the study period. The average area in this period is 261 thousand hectares, average production 568.3 thousand tonnes and average yield 54.4 mounds per hectare during the same period.

Table 4.1: Area, production and yield of wheat in Faisalabad

Years	Area 000 Hectares	Production 000 Tonnes	Yield Mounds/acre
1979-80	267.0	353.2	33.07
1980-81	266.3	367.5	34.51
1981-82	265.5	381.9	35.96
1982-83	264.8	396.2	37.40
1983-84	264.0	410.5	38.88
1984-85	263.3	424.9	40.34
1985-86	262.6	439.2	41.82
1986-87	265.8	416.2	39.15
1987-88	256.5	440.9	42.98
1988-89	257.4	565.5	54.93
1989-90	260.2	506.4	48.66
1990-91	258.6	479.3	46.34
1991-92	260.2	548.4	52.69
1992-93	254.1	492.5	48.46
1993-94	257.4	564.1	54.78
1994-95	260.2	618.7	59.45
1995-96	260.6	559.8	53.70
1996-97	255	623.7	61.16
1997-98	246.5	574.1	58.22
1998-99	252.9	625.7	61.85
1999-2000	252.1	640.0	63.45
2000-01	262.2	766.9	73.11
2001-02	250.1	651.8	65.16
2002-03	254.1	716.3	70.47
2003-04	265.1	789.2	74.42
2004-05	276.8	632.7	57.16
2005-06	273.6	793.5	72.49
2006-07	263.5	817.1	77.53
2007-08	265.9	697.4	65.58
2008-09	272.65	755.35	69.26

Sources: GOP (Various issues, Agricultural Statistics of Pakistan).

The following Figure 4.1 and 4.2 shows that the production and yield of wheat has increased over time but the area have remain static in the period ranging from 1979 to 2009. This points to the above mentioned fact that the variables other than area are responsible for explaining the wheat yield increase overtime in the Faisalabad district. Based on this point the coefficient of area variable in the regression analysis is expected to be either non-significant or of very low value.

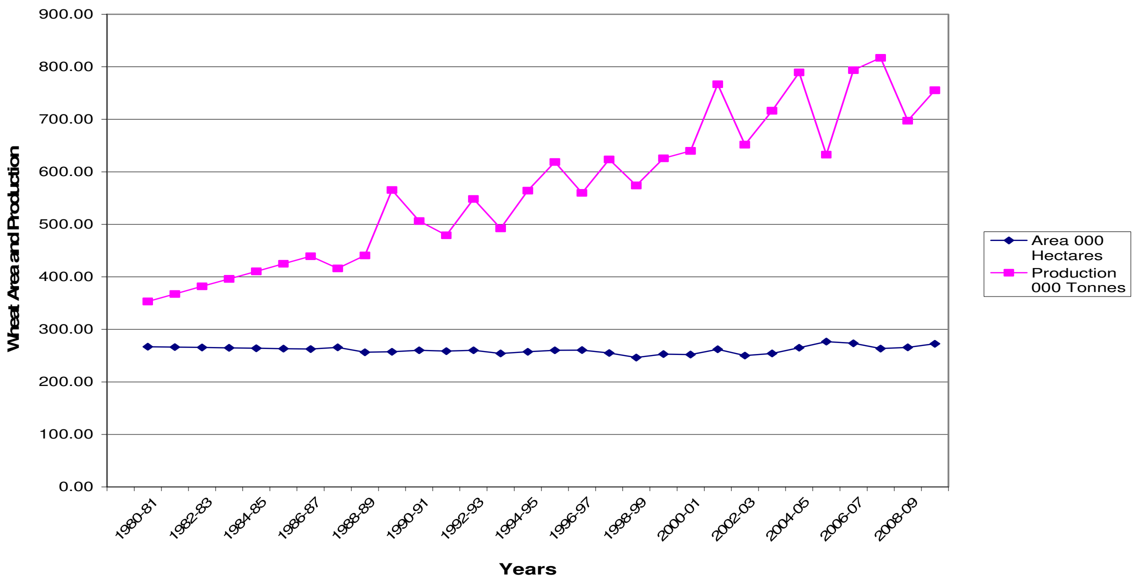

Figure 4.1: Area and Production of wheat from 1979 to 2009 in Faisalabad

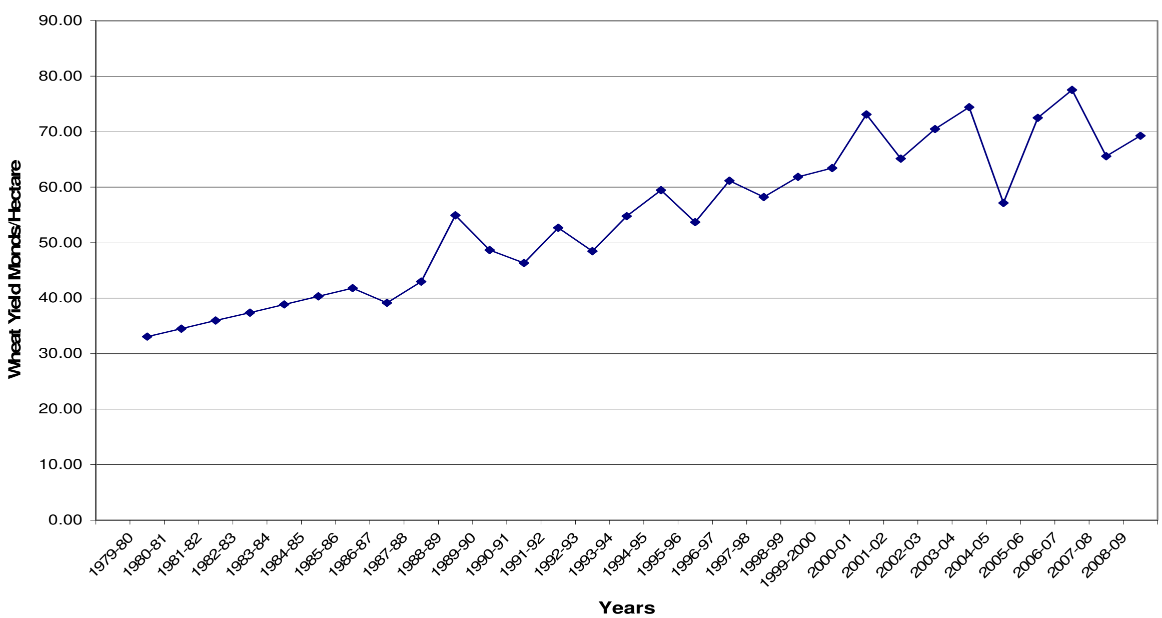

Figure 4.2: Wheat yield from 1979 to 2009 in Faisalabad

Different variable are involved in the estimation supply response function of wheat including economic, location and climate variables. The most important economic variables are the input and output prices for wheat. The prices of wheat vary affecting the farmers decision of how much to produce and how to produce as well. Wheat prices, in Faisalabad, for the month of March 2010 were Rs. 1064 per 40kg showing an increase of 21.06% over previous year prices at the same time. Over all, in Punjab, an increase of 16.44% in March 2010 prices and March 2009 prices was observed (AMIS).

With the increase in wheat prices farmers use more of inputs to increase production, while with the increase of input prices less of it is used resulting in lower productivity. The prices of inputs do vary influencing the level of their use. The above two arguments are true as the cost of production of wheat has increased by above 5% from 2008-09 to 2009-10 (AMIS).

The annual average wheat prices obtained by taking average of monthly wheat prices in Faisalabad district show a steady increase except after 2007-08 price hikes of procurement prices by government.

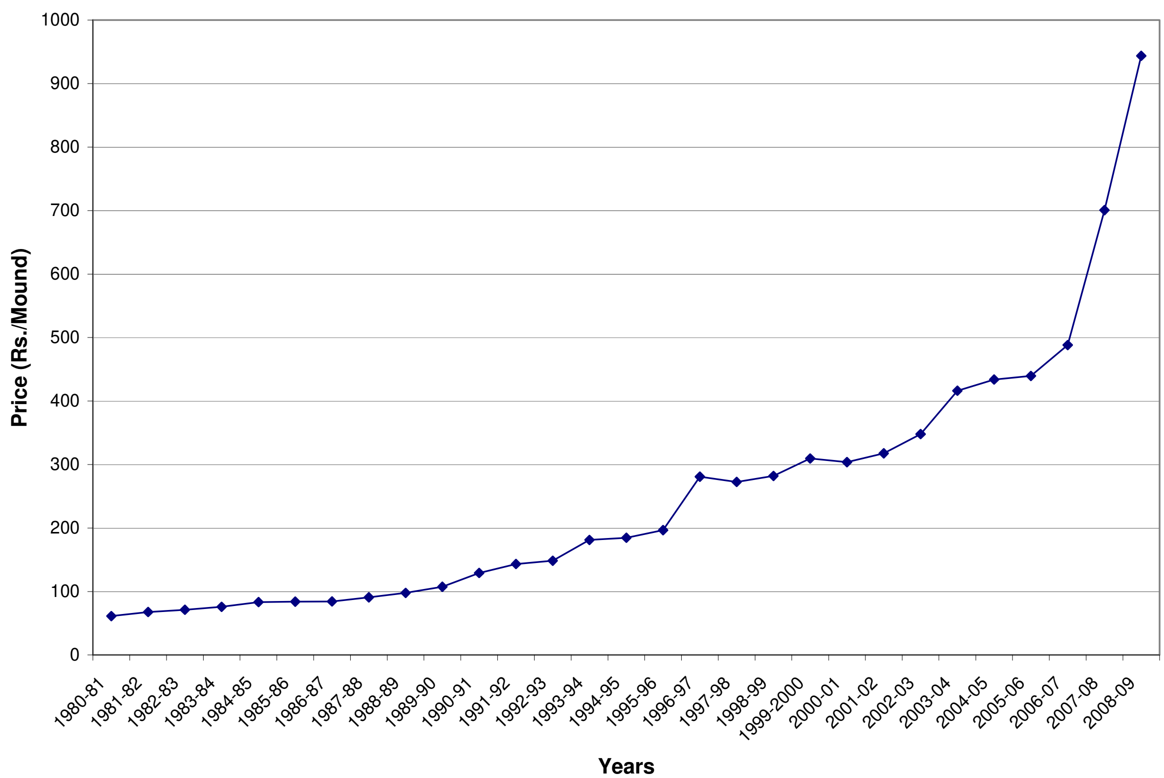

Figure 4.3: Annual average wheat price from 1979 to 2009 in Faisalabad

Table 4.2 explains the mean maximum temperature of Faisalabad district for wheat growing months, its six month average and covariance. The average mean maximum temperature for the six months is around 27 ºC for the study period. A study projected that the global temperature would increase by 1.4–5.8°C because of projected increases in the concentrations of all greenhouse gases by the end of the 21st century (Houghton *et al.*, 2001). It may have many implications for Pakistan agriculture in general and on wheat in particular.

Table 4.2: Mean maximum monthly temperature (^oC) of wheat growing season in Faisalabad

Years	Nov	Dec	Jan	Feb	Mar	Apr	Average	cov
1979-80	33.3	26.8	19.0	22.7	24.5	35.6	26.983	0.526
1980-81	32.5	26.4	19.4	22.6	25.3	34.9	26.850	0.545
1981-82	32.7	26.2	19.3	19.3	22.7	31.6	25.300	0.565
1982-83	32.0	27.2	18.4	21.0	25.1	28.6	25.383	0.504
1983-84	33.0	26.2	18.9	19.8	29.6	33.2	26.783	0.427
1984-85	31.9	27.3	19.1	24.4	29.7	33.5	27.650	0.440
1985-86	31.4	27.2	19.3	21.0	25.8	33.2	26.317	0.453
1986-87	33.0	28.5	21.3	23.3	26.2	34.6	27.817	0.441
1987-88	33.2	27.9	20.8	24.1	26.2	36.0	28.033	0.451
1988-89	34.1	27.0	19.0	21.4	25.7	32.5	26.617	0.445
1989-90	31.7	27.9	20.3	20.8	25.2	33.1	26.500	0.456
1990-91	32.1	27.2	19.2	20.8	25.4	31.2	25.983	0.469
1991-92	32.9	26.3	19.7	20.1	26.0	31.3	26.050	0.445
1992-93	33.0	28.4	19.2	24.8	25.1	33.8	27.383	0.404
1993-94	32.1	27.9	19.7	20.7	28.9	32.4	26.950	0.428
1994-95	33.9	28.0	19.3	22.0	25.5	30.9	26.600	0.454
1995-96	32.2	27.2	19.6	22.4	27.3	34.9	27.267	0.475
1996-97	27.7	24.7	19.7	22.8	26.5	31.0	25.400	0.508
1997-98	32.9	28.5	19.6	21.8	25.5	34.2	27.083	0.192
1998-99	34.2	28.3	15.8	22.6	27.6	37.7	27.700	0.192
1999-2000	35.2	27.8	18.3	20.7	27.3	37.5	27.800	0.207
2000-01	34.4	28.3	16.6	23.9	29.2	33.8	27.700	0.217
2001-02	32.9	27.7	19.4	22.4	29.7	36.2	28.050	0.246
2002-03	33.3	26.6	16.7	21.7	26.7	35.3	26.717	0.233
2003-04	30.7	27.5	18.6	23.8	32.4	37.4	28.400	0.228
2004-05	33.5	27.6	18.0	18.9	26.1	33.6	26.283	0.191
2005-06	32.8	25.8	19.4	26.1	26.6	36.0	27.783	0.011
2006-07	34.1	28.4	20.2	21.5	25.8	38.1	28.017	0.015
2007-08	34.0	28.1	17.5	21.1	31.2	33.5	27.567	0.005
2008-09	33.5	26.2	20.2	23.4	28.3	34.0	27.600	0.000
Total Avg	**32.81**	**27.3**	**19.05**	**22.06**	**26.9**	**33.99**	**27.018**	

Source: GOP (Various issues Pakistan Meteorological Department).

The following Figure 4.4 shows significant variation in the average mean maximum temperature for the study period. In the early years the fluctuations seem more pronounced while keeping the temperature on lower side. While in the recent years there had been not only increase in overall average temperature but also the variations has been on both sides, lower and higher. The average maximum temperature has increased overtime by almost 1.5^{o}C in the previous 30 years. The increase in average maximum temperature has very strong implications for cereals and wheat production in particular. **IPCC (2001)** concluded in its third assessment report that average crop yield was expected to drop down to 50% in Pakistan due to change in climatic conditions and subsequent decreased availability of water and new or changed insect pest incidence.

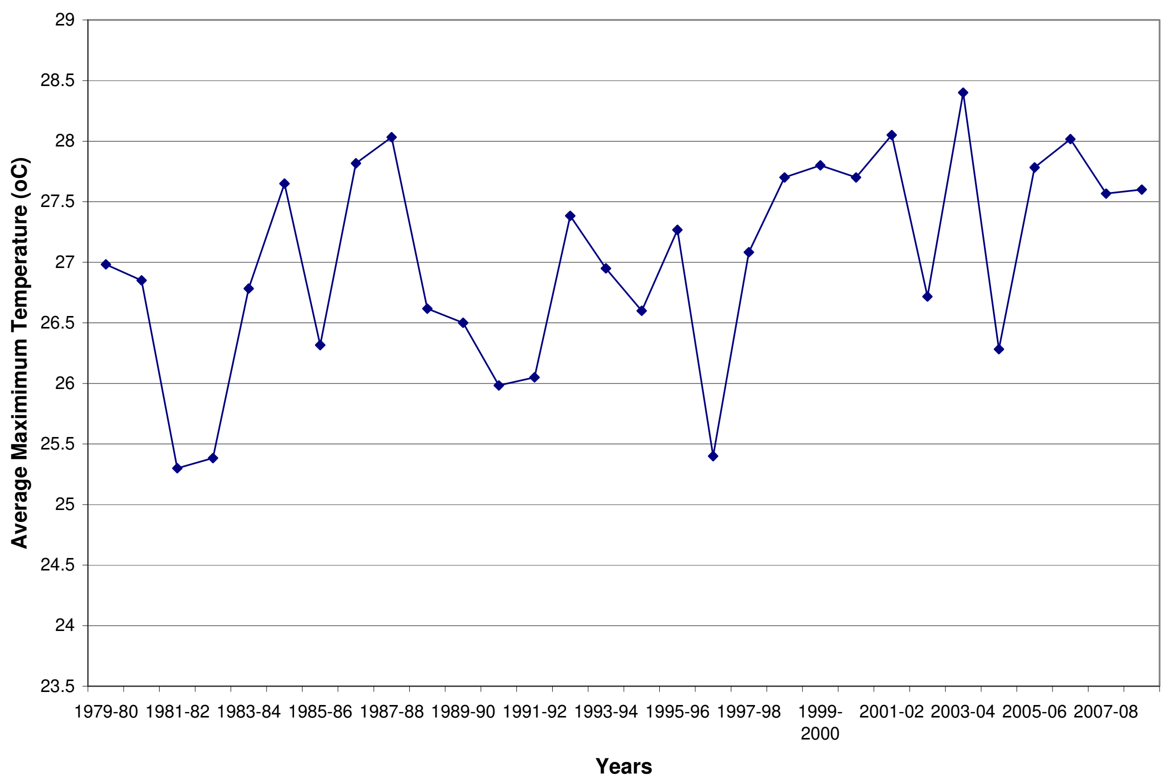

Figure 4.4: Average maximum temperature in Faisalabad for wheat growing season from 1979 to 2009

Table 4.3 explains the mean minimum temperature of Faisalabad district for wheat growing months, its six month average and covariance. The average mean minimum temperature for the six months is around 12 ºC for the study period.

Table 4.3: Mean minimum monthly temperature (ºC) of wheat growing season in Faisalabad

Years	Nov	Dec	Jan	Feb	Mar	Apr	Average	Cov
1979-80	17.8	10.1	3.3	7.6	12.4	19.3	11.750	0.333
1980-81	15	8.5	5.5	8.7	12.6	17.6	11.317	0.346
1981-82	16.9	10.1	4.8	6	11.5	17.3	11.100	0.359
1982-83	16.5	9.3	3.7	6.6	11	15.9	10.500	0.332
1983-84	14.6	10.2	2.1	4.7	13.9	18.9	10.733	0.262
1984-85	16.8	11.8	4.2	6.3	12.1	18.7	11.650	0.259
1985-86	18	11.2	2.6	6.9	12.2	17.6	11.417	0.275
1986-87	17.1	10.1	5.5	8.4	14.3	18.7	12.350	0.261
1987-88	17.2	10.2	6	7.9	12.2	18.6	12.017	0.269
1988-89	16.7	10.8	4.5	5.7	12.3	16.2	11.033	0.286
1989-90	17.3	11.3	6.8	8.5	11.6	16.4	11.983	0.273
1990-91	16.3	11	4.4	6.6	12.1	16.7	11.183	0.285
1991-92	17.3	10.9	6.3	7.1	12	17.3	11.817	0.258
1992-93	16.7	11.9	4.6	8.9	11.3	18.3	11.950	0.249
1993-94	16.2	11.9	4.9	6.8	13.8	16.9	11.750	0.271
1994-95	17.9	10.4	4.4	8.3	11.5	16.7	11.533	0.285
1995-96	16.8	9.2	4.6	7.9	14.6	18.3	11.900	0.293
1996-97	17.3	11.1	3.5	5.9	12.2	17.1	11.183	0.302
1997-98	19.4	10	3.9	7.7	12	19.1	12.017	0.104
1998-99	19	11.5	7.5	8.6	13.1	18.5	13.033	0.095
1999-2000	18.3	11.1	4.8	6.4	11.6	19.9	12.017	0.084
2000-01	18.9	11.3	4.3	6.8	12.7	19.2	12.200	0.123
2001-02	18.8	14.7	4.6	7.3	13.1	19.9	13.067	0.135
2002-03	17.5	10.2	5	7.6	13.3	19.7	12.217	0.112
2003-04	17.2	12.3	6.6	8.7	15	21.4	13.533	0.111
2004-05	17.8	11	4.2	8	14.5	16.9	12.067	0.039
2005-06	19.4	13.2	4.4	11.5	13.5	19.5	13.583	-0.026
2006-07	16.4	11.7	3.7	8.9	12.5	20	12.200	-0.012
2007-08	19.6	10.8	3.4	6.1	15	18.7	12.267	-0.018
2008-09	16.5	9.9	6.1	8.6	13.3	18.4	12.133	0.000
Total Average	**17.37**	**10.92**	**4.67**	**7.50**	**12.77**	**18.26**	**11.92**	

Source: GOP (Various issues Pakistan Meteorological Department).

The following Figure 4.5 shows very little variation in the average mean minimum temperature for the study period as it revolved in between 10.5 and 13.5. This apparently suggests very small impact of mean minimum temperature on wheat yield.

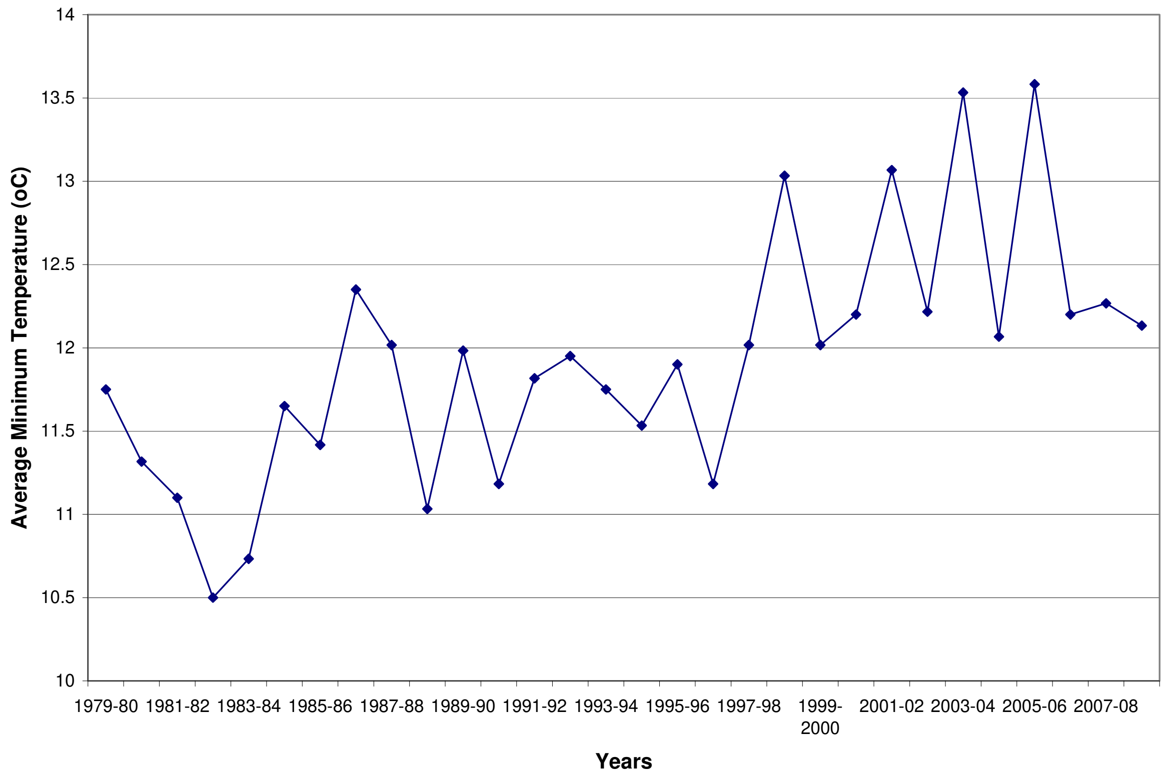

Figure 4.5: Average minimum temperature in Faisalabad for wheat growing season from 1979 to 2009

Table 4.4 shows mean monthly rainfall of wheat growing season, its average and covariance in Faisalabad. The average monthly rainfall for the growing season during 1979-2009 is 14.3 millimeter.

Table 4.4: Mean monthly rainfall (millimeter) of wheat growing season in Faisalabad

Years	Nov	Dec	Jan	Feb	Mar	Apr	Average	Cov
1979-80	6.1	9.7	18	2.8	33.9	16.3	14.433	53.719
1980-81	7.6	0	30	1.2	69.1	0	18.017	55.559
1981-82	0	11	13	21.4	80.7	49.7	29.250	54.451
1982-83	0	0	0	36.8	6.3	36.6	13.283	51.234
1983-84	0	7.8	3	24.8	3.3	16	9.150	53.361
1984-85	11.9	3	2	0	1.5	51.2	11.600	55.474
1985-86	2.6	0	4.1	17.6	20	10.1	9.067	56.667
1986-87	0	0	3.6	35	47	22.3	17.983	58.823
1987-88	0	0	4.1	3	44.1	4.5	9.283	61.466
1988-89	0	0	28	3.5	24.3	3.8	9.917	63.753
1989-90	0	0	27	79.4	46.3	16.2	28.083	65.602
1990-91	1	0	0	21	12.8	115	24.950	65.411
1991-92	0	0.5	29	13.7	8.5	39.9	15.250	74.684
1992-93	0	0	1.6	7	9.7	25.7	7.333	79.057
1993-94	0	1	3.3	8.9	0.3	11	4.083	80.963
1994-95	0	0	1.5	10	0.5	6.9	3.150	76.315
1995-96	3.3	0	2.3	17.8	40	0	10.567	67.048
1996-97	39	18	19	13	9.3	56.2	25.817	70.611
1997-98	1.6	0	0	16.3	12.5	66.1	16.083	43.893
1998-99	24.3	1	33	5.7	8.5	0	12.000	48.569
1999-2000	0	0	9.5	7.6	0.1	0	2.867	50.139
2000-01	0	2.6	5	0.7	0.2	37.4	7.650	34.466
2001-02	3.3	0.5	0.2	2.5	16.1	2.8	4.233	34.748
2002-03	0	1.3	0	84	54.7	2	23.667	15.413
2003-04	18	6.6	25	6	0	34.3	15.017	23.864
2004-05	0	0	26	42.4	112	6.2	31.183	25.455
2005-06	20	9	8.3	12.5	31.1	0	13.483	14.476
2006-07	0	0	0	37.2	34.4	0	11.933	19.025
2007-08	0	0	46	18.2	0	35	16.483	12.634
2008-09	8.5	0	12	18.4	12	34.8	14.317	0.000
Total Average	**4.91**	**2.40**	**11.82**	**18.95**	**24.64**	**23.33**	**14.34**	

Source: GOP (Various issues Pakistan Meteorological Department).

The following Figure 4.6 shows that average rainfall has fluctuated very highly suggesting a very variable influence on wheat yield in Faisalabad.

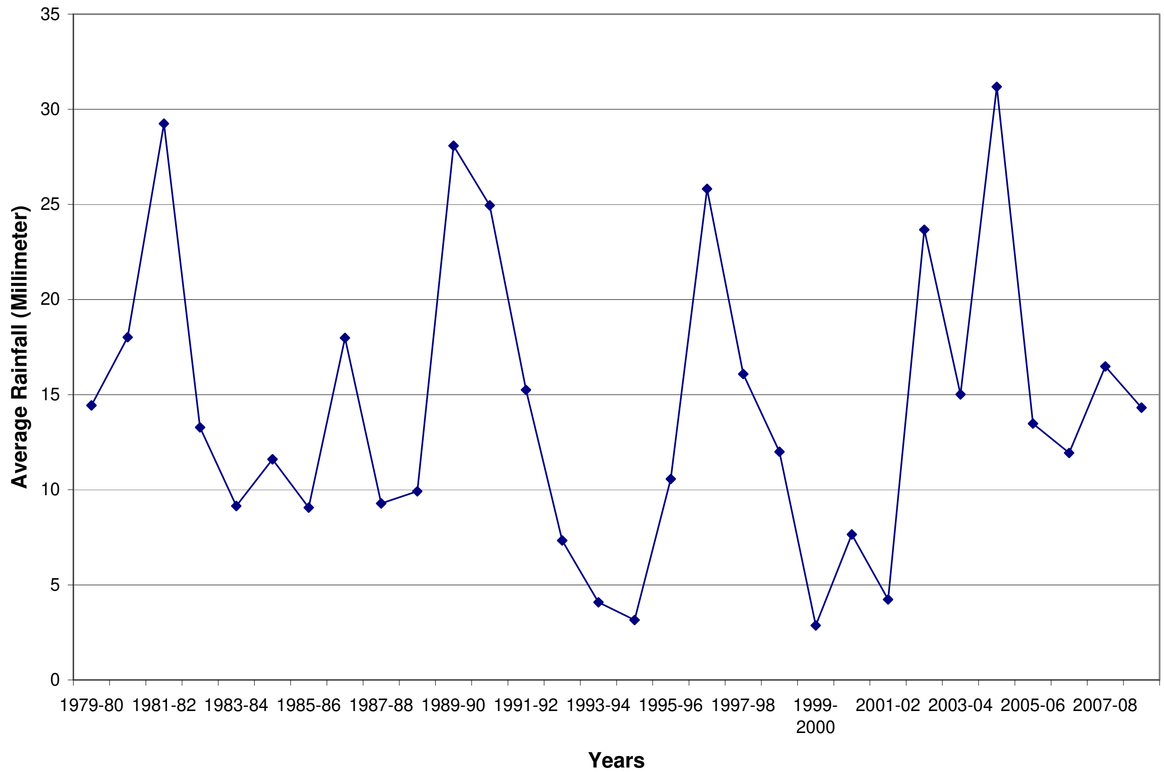

Figure 4.6: Average rainfall in Faisalabad for wheat growing season from 1979 to 2009

4.1.2 Overtime Performance of Wheat Crop in Bahawalpur

The area, production and yield of wheat in Bahawalpur district from 1979 to 2009 is given below. As is clear from the following Table 4.5 area has increased more than that of Faisalabad district. It increased from 174.6 thousand hectares to 282.4 thousand hectares from 1979 to 2009 increasing by around 62% in 30 years while yield has increased around 124% in this period. The average area in this period is 233.9 thousand hectares, average production 508.45 thousand tonnes and average yield 52.59 mounds per hectare during the same period.

Table 4.5: Area, production and yield of wheat in Bahawalpur

Years	Area 000 Hectares	Production 000 Tonnes	Yield Mounds/acre
1979-80	174.6	221.8	31.76
1980-81	178.8	240.1	33.59
1981-82	182.9	258.5	35.32
1982-83	187.1	276.8	37.00
1983-84	191.3	295.2	38.58
1984-85	195.4	313.5	40.11
1985-86	199.6	331.9	41.57
1986-87	203.2	355.3	43.72
1987-88	199.9	341.6	42.73
1988-89	215.3	424.0	49.23
1989-90	216.5	384.4	44.39
1990-91	221.8	391.5	44.14
1991-92	213.7	438.7	51.33
1992-93	255.8	567.1	55.43
1993-94	234.3	445.4	47.52
1994-95	228.6	476.6	52.12
1995-96	243.6	478.7	49.13
1996-97	234.3	556.7	59.40
1997-98	252.5	553.2	54.78
1998-99	253.7	570.3	56.22
1999-2000	257.8	588.7	57.08
2000-01	271.9	663.2	60.98
2001-02	269.9	638.0	59.11
2002-03	268.7	723.9	67.36
2003-04	267.9	901.7	84.15
2004-05	271.5	737.6	67.93
2005-06	289.9	749.2	64.62
2006-07	279.2	812.8	72.79
2007-08	276.8	713.7	64.47
2008-09	282.4	803.5	71.14
Total average	**233.96**	**508.45**	**52.59**

Sources: GOP (Various issues Agricultural Statistics of Pakistan)

The following Figure 4.7 makes clear the above mentioned point that the increase in area is very marginal as compared to increase in wheat production. Thus it is imperative from the figure that production has increased much more than that of area in Bahawalpur virtually above 200% more, production increase has been 262% from 1979 to 2009. Thus there are some factors other than area which explain increase in production, so wheat yield response function determination becomes handy.

Similarly wheat yield has shown steady increasing trend while boosting up in the current years as shown in Figure 4.7.

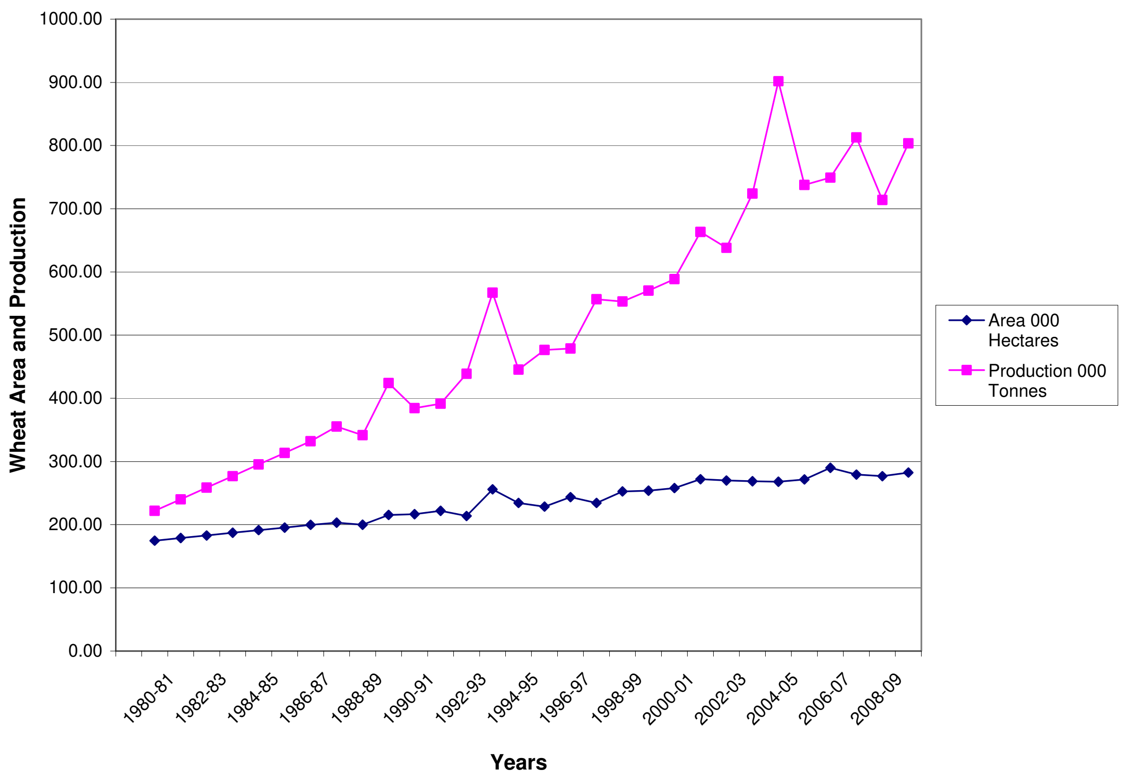

Figure 4.7: Area and Production of wheat for 1979-2009 in Bahawalpur

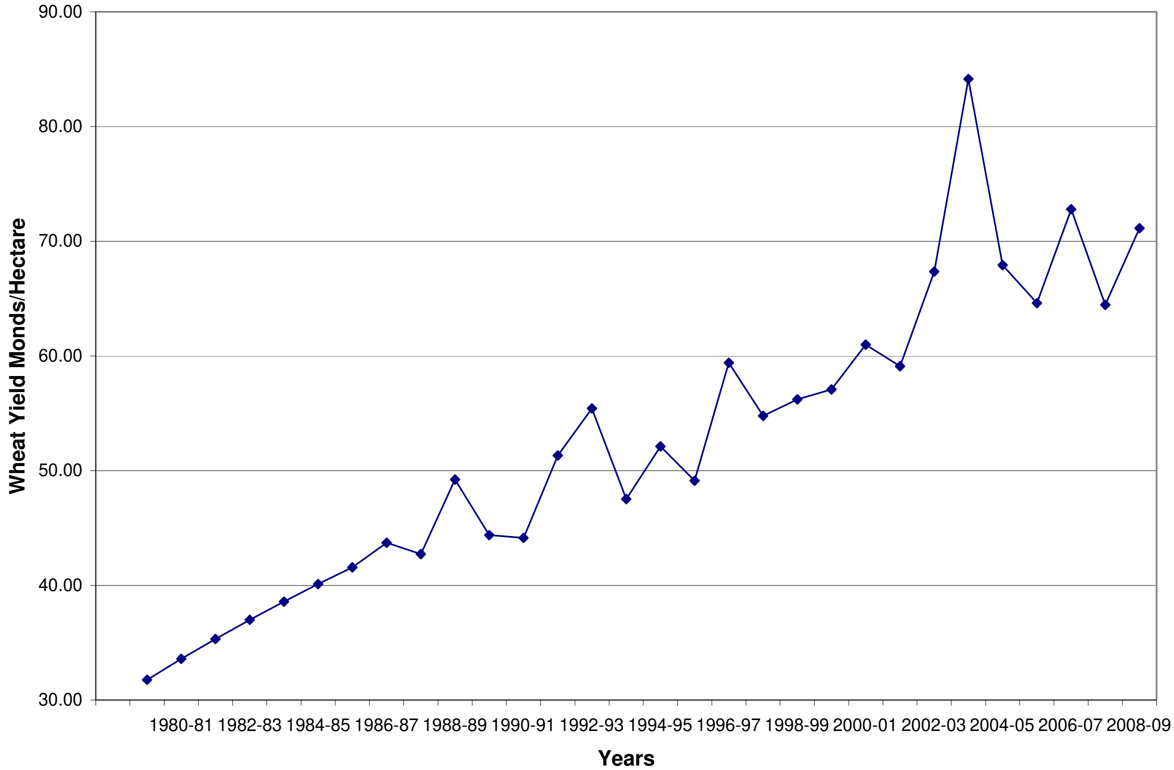

Figure 4.8: Wheat yield for 1979-2009 in Bahawalpur

The prices of wheat vary affecting the farmers decision of how much to produce and how to produce as well. Wheat prices, in Bahawalpur, for the month of March 2010 were Rs. 1039 per 40kg showing an increase of 15.10% over previous year prices at the same time. Over all, in Punjab, an increase of 16.44% in March 2010 prices and March 2009 prices was observed[3].

The prices of wheat has been highest in the wheat growing months (table of average monthly prices of wheat is given in appendix), the reason being the shortage of wheat in these months may be due to less storage capacity of the wheat marketing system in Bahawalpur. The average annual wheat price in Bahawalpur has been very high in the last two years.

[3] Agri Marketing Round up Page 5, March 2010, Agriculture Marketing Govt. of Punjab

Annual average wheat price in Bahawalpur shown a steady increase till 1995 then the prices started increasing highly and after 2006-07 the prices soured at unprecedented rate. The last increase in the prices of wheat in Bahawalpur is the same as at the country level because of an increase in the procurement prices announced by the government (Agriculture Policy Institute, Islamabad). Looking at this graph and considering the previous graph of wheat yield it comes to our understanding that there exists indeed some relationship of changes in wheat prices and yield level in Bahawalpur i.e., there do exist some yield response of wheat towards change in wheat prices. Thus this variable was included in the analysis as part of the input change variable.

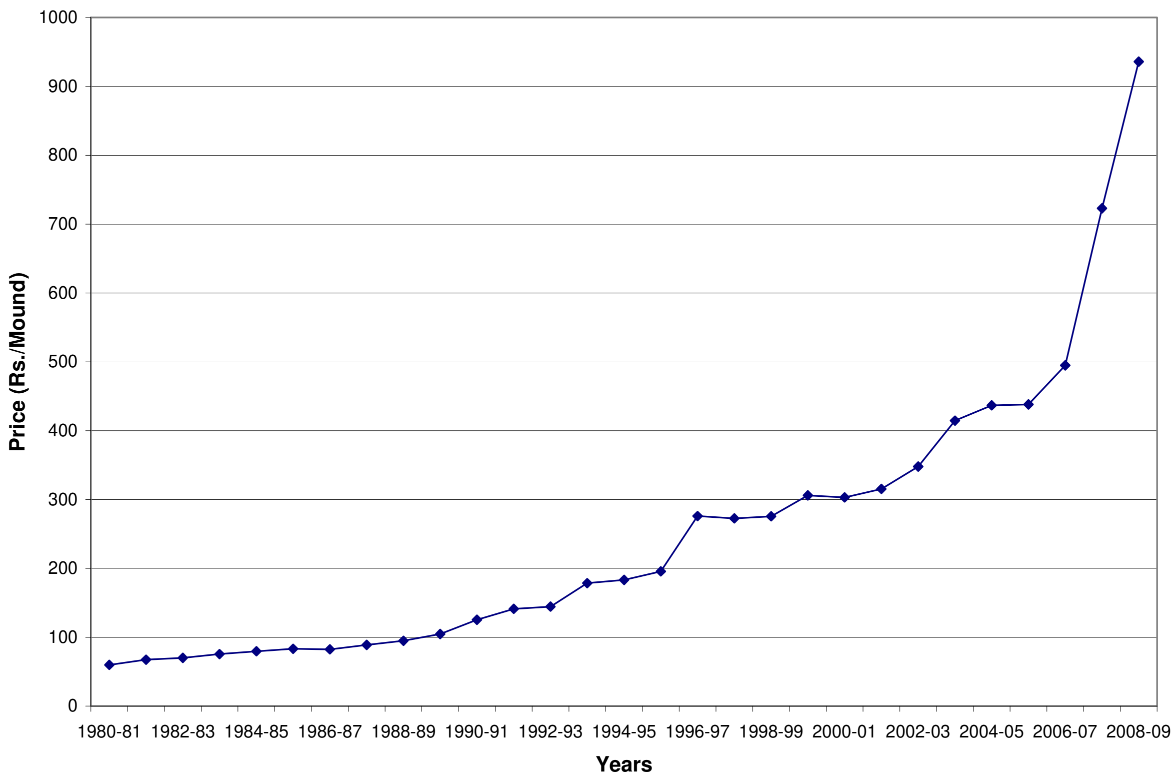

Figure 4.9: Annual average wheat price from 1979 to 2009 in Bahawalpur

The Table 4.6 shows mean monthly temperature for the wheat growing season, its average and covariance. The average mean maximum temperature has been 27°C in the six months.

Table 4.6: Mean maximum monthly temperature (°C) of wheat growing season in Bahawalpur

Years	Nov	Dec	Jan	Feb	Mar	Apr	Average	Cov
1979-80	28.5	23.4	21.3	25.3	25.1	38.5	27.017	1.181
1980-81	28.5	25.2	21	24.9	28.1	37.4	27.517	1.223
1981-82	28	21.4	21.2	21.2	25.1	35.1	25.333	1.258
1982-83	29.2	22.4	19.8	22.4	27.1	31.9	25.467	1.254
1983-84	27.9	22.9	20.1	21.1	31.6	34.6	26.367	1.237
1984-85	28.3	22.9	20.9	26.2	30.9	35.1	27.383	1.273
1985-86	29.4	21.9	21	22.9	28.2	35.5	26.483	1.326
1986-87	30	24.5	22.6	24.5	27.7	37.1	27.733	1.362
1987-88	0	23.4	22.9	26	29.1	38.6	23.333	1.417
1988-89	29	22.3	20.3	22.8	27.7	34.6	26.117	0.597
1989-90	29.7	23.3	22.7	22.3	27.2	35.4	26.767	0.561
1990-91	29.4	24.4	21.1	22.4	28.1	33.2	26.433	0.575
1991-92	28.5	25	21.2	22.4	27.5	33.4	26.333	0.575
1992-93	31.6	26	21.1	27	27.4	36.4	28.250	0.530
1993-94	30.7	23.7	21.8	22.7	30.8	34.7	27.400	0.544
1994-95	29.6	23	20.9	24.4	27.2	32.4	26.250	0.573
1995-96	28.3	24.9	21.5	24.2	29.2	36.2	27.383	0.544
1996-97	26.7	20.5	22.3	25.4	28.3	34.3	26.250	0.573
1997-98	30.3	22.1	22.1	23.7	27.8	37	27.167	0.395
1998-99	30.8	26.1	18.6	23.7	30.4	39.3	28.150	0.408
1999-2000	30.3	25.9	20	22.3	29.8	39.8	28.017	0.444
2000-01	31.3	25.9	20.9	25.1	31	36.7	28.483	0.491
2001-02	29.9	25.2	22.3	24.7	31.9	39	28.833	0.528
2002-03	29.7	24.8	21.8	23.5	29.9	38.5	28.033	0.425
2003-04	30.8	25.1	20.4	25.9	34.2	40.5	29.483	0.478
2004-05	29.8	24.7	19.7	20.4	28.3	36.9	26.633	0.124
2005-06	28.4	22.8	20.7	27.1	29.1	38.7	27.800	0.097
2006-07	30.2	22.6	22.4	23.7	27.1	39	27.500	0.058
2007-08	30	23.6	18.7	22.8	32.5	35	27.100	0.073
2008-09	28.7	24.7	21.5	24.8	29.8	35.9	27.567	0.000
Total average	**28.45**	**23.82**	**21.09**	**23.86**	**28.94**	**36.36**	**27.09**	

Source: GOP (Various issues Pakistan Meteorological Department).

The Figure 4.10 shows that the average maximum temperature for the wheat growing season remained very close to its mean 27^{o}C in Bahawalpur. It is clear from the figure that there exists little variation in maximum temperature for the period 1979-2009. The variation in mean maximum temperature of Bahawalpur is much less than that of Faisalabad. Although the average maximum temperature is higher than Faisalabad but less variability overtime suggests more planning possibilities on the part of farm management and thus greater scope for risk aversion.

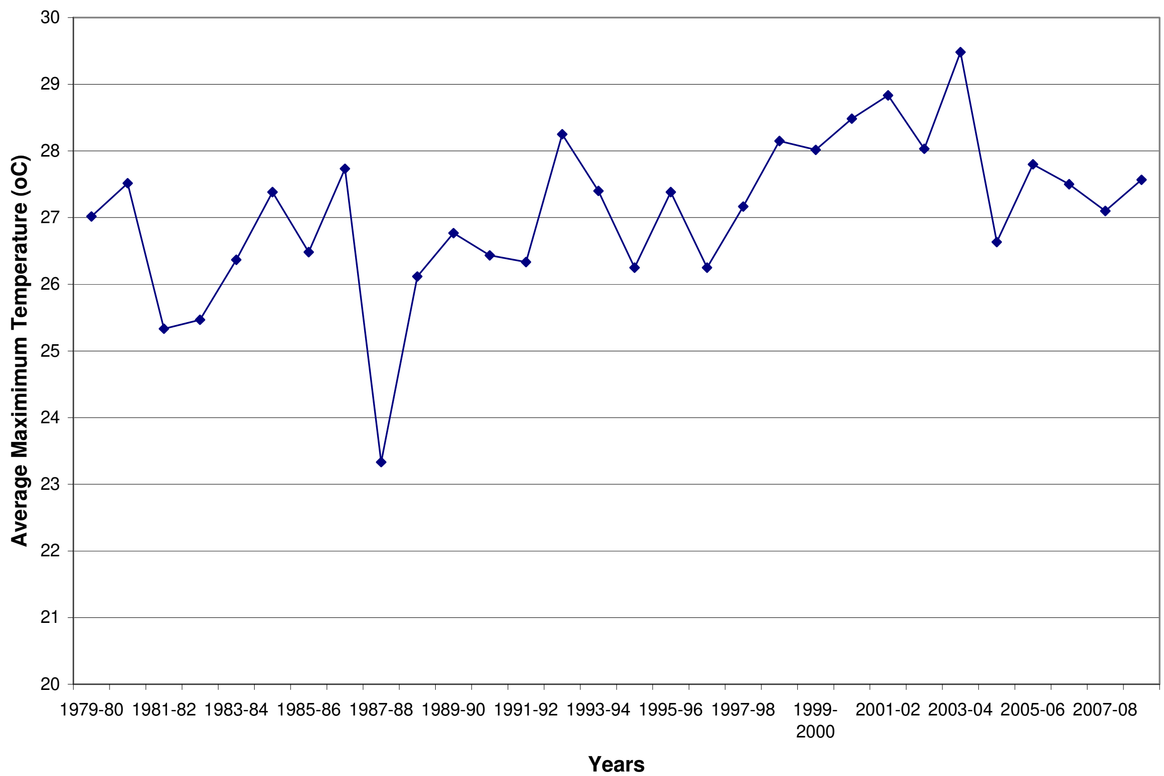

Figure 4.10: Average maximum temperature in Bahawalpur for wheat growing season from 1979 to 2009

Table 4.7 explains the mean minimum temperature of Bahawalpur district for wheat growing months, its six month average and covariance. The average mean minimum temperature for the six months is around 11.2 ºC for the study period. The minimum temperature also remained around its average for the period from 1979 to 2009 as was the case of Faisalabad.

Table 4.7: Mean minimum monthly temperature (°C) of wheat growing season in Bahawalpur

Years	Nov	Dec	Jan	Feb	Mar	Apr	Average	Cov
1979-80	11.5	7.3	5.7	9	13.8	21.4	11.450	0.550
1980-81	11.4	7	7.2	9.9	14.5	20.4	11.733	0.564
1981-82	12.8	7.4	6.3	7.5	13.1	19.5	11.100	0.574
1982-83	11.1	6.5	5.5	8.9	12	14.7	9.783	0.596
1983-84	11.7	6	3.7	5.4	14.7	18.7	10.033	0.579
1984-85	12.1	6.6	5.7	8.1	13.7	19.8	11.000	0.575
1985-86	12	4.8	3.8	8.1	13.3	18.8	10.133	0.596
1986-87	11.3	5.6	6.7	9.8	15.7	20	11.517	0.584
1987-88	0	7.9	7	9.6	14	20.8	9.883	0.610
1988-89	13.1	8.1	5.3	7.5	13.6	17.8	10.900	0.486
1989-90	13	7.2	7.7	9.7	12.3	18.7	11.433	0.493
1990-91	12.1	8.3	5.3	8	13.7	18.5	10.983	0.520
1991-92	12.4	9.2	6.9	9.4	13.3	17.9	11.517	0.544
1992-93	13.2	7.1	6.2	9.9	11.6	18.9	11.150	0.576
1993-94	13.6	7.7	6.2	8.3	14.6	17.6	11.333	0.604
1994-95	11.3	7.3	5.5	9.5	12.2	17.2	10.500	0.634
1995-96	10.2	4.7	5.7	8.5	14.8	18.4	10.383	0.599
1996-97	13	7.1	5.6	7.9	13.5	17.8	10.817	0.471
1997-98	11.5	6.3	5.4	8.7	13.3	20.7	10.983	0.432
1998-99	12.1	7.2	6.7	10.3	13.9	19.6	11.633	0.432
1999-2000	12	7	6	7.6	13	21.4	11.167	0.458
2000-01	12.8	8.1	4.9	7.5	13	19.1	10.900	0.493
2001-02	13.5	8.3	5.7	7.8	14.5	21.9	11.950	0.431
2002-03	10.6	8.2	5.5	9.3	13.5	19.4	11.083	0.493
2003-04	12.7	10.8	7.8	9.5	16.2	22.1	13.183	0.441
2004-05	12.3	5.4	5.6	9.3	15.8	19	11.233	0.343
2005-06	14.7	8.3	6.2	11.9	14.5	21	12.767	0.279
2006-07	13.4	7.2	10	11	14.5	22.3	13.067	0.231
2007-08	11.8	9.5	4.9	6.9	15.7	19.3	11.350	-0.017
2008-09	12	8	7.3	9.9	14.3	19.1	11.767	0.000
Total average	**11.84**	**7.34**	**6.07**	**8.82**	**13.89**	**19.39**	**11.22**	

Source: GOP (Various issues Pakistan Meteorological Department).

The Figure 4.11 shows that the average mean minimum temperature of wheat growing season of Bahawalpur for the period 1979-2009 shows little variation. This is the same result as obtained for Faisalabad, little variation in average minimum temperature for the wheat growing season from 1979 to 2009. As the mean minimum temperature for both Faisalabad and Bahawalpur remained almost static for the whole period it is expected that there will be little or no influence of it on the wheat yield response function. Although in theory it is expected that mean minimum temperature will have some affect on yield especially at the sowing stage of crop but in this particular case the affect is likely to be negligible. The reason behind this may be that in both Faisalabad and Bahawalpur the minimum temperature is well above the critical low temperature necessary for seedlings to grow. The impact of minimum temperature will be more pronounced in regions where temperature often falls below the minimum critical temperature of wheat growth.

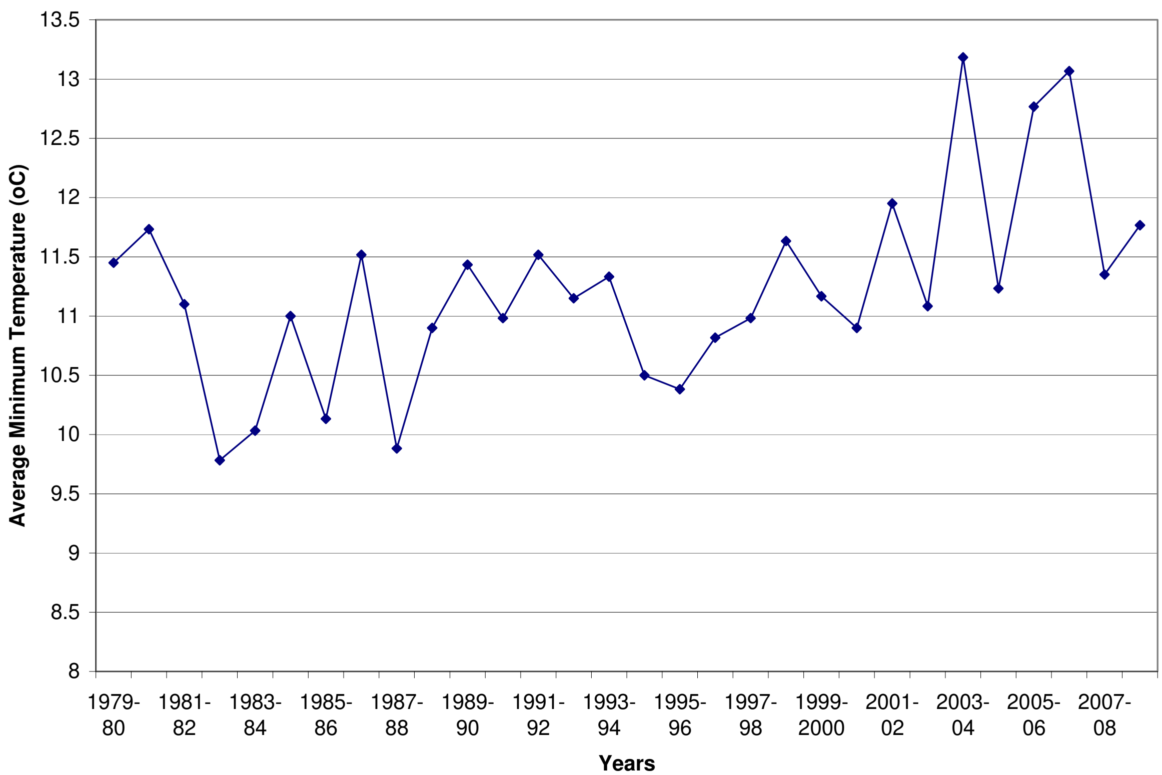

Figure 4.11: Average minimum temperature in Bahawalpur for wheat growing season from 1979 to 2009

Table 4.8 shows the monthly rainfall, its average and covariance from November to April for the period from 1979 to 2009 for Bahawalpur. The average rainfall for the whole period is 7.68 millimeter. Rainfall is very important for the growth of many crops as well as for all living things in a proper amount and at an appropriate time.

Table 4.8: Mean monthly rainfall (millimeter) of wheat growing season in Bahawalpur

Years	Nov	Dec	Jan	Feb	Mar	Apr	Average	Cov
1979-80	1.3	41.7	2.9	0	13.8	1.1	10.133	9.367
1980-81	3.3	0	4.7	15.9	3.8	1	4.783	9.892
1981-82	9.2	0.6	5.8	7.2	45.1	30.8	16.450	9.882
1982-83	0	0	13.6	10.4	2.1	48.5	12.433	11.264
1983-84	1.2	2.8	0	9	3.1	12.2	4.717	9.968
1984-85	0	0	0	0	2.4	20.2	3.767	9.793
1985-86	1	0	0	1.5	6.3	3.3	2.017	9.311
1986-87	0	0	6	12.1	15.7	6.2	6.667	10.412
1987-88	0	0.5	8	0.5	25	0	5.667	10.633
1988-89	12	13.5	18.5	0.7	7	3.2	9.150	10.778
1989-90	1	0	3	40.4	4.5	3	8.650	10.608
1990-91	0	0.3	0	0.5	1.2	37	6.500	11.435
1991-92	1.5	0	40.6	22.5	1.2	7	12.133	11.391
1992-93	0	0	3	2	18.1	2.4	4.250	7.416
1993-94	0	7.7	5.3	4.7	0	11	4.783	7.311
1994-95	0	1.5	9.9	4.3	4	11.7	5.233	9.105
1995-96	0	0	6.4	12.5	17.4	4	6.717	10.390
1996-97	8.6	0.5	9	2	10	5.3	5.900	10.580
1997-98	0	0	3.6	11	7.5	31	8.850	13.798
1998-99	0	0	11.5	26	4.5	0	7.000	15.039
1999-2000	0	0	12	11	0	0	3.833	16.116
2000-01	0	0	0	2	0	16.4	3.067	14.098
2001-02	1.7	0	0	0	2	3.2	1.150	16.828
2002-03	0	0	0	18.5	0.6	1	3.350	4.720
2003-04	0	46	22.4	0	0	3	11.900	5.522
2004-05	0	0	4	45.1	28	1	13.017	6.413
2005-06	5	14.6	0.2	0	37.8	12.6	11.700	7.909
2006-07	0	7.4	0	29.6	43	0	13.333	10.251
2007-08	0	48	2.3	11	0	34	15.883	13.230
2008-09	0	0	28	0	8.4	7.2	7.267	0.000
Total average	**1.53**	**6.17**	**7.36**	**10.01**	**10.42**	**10.58**	**7.68**	

Source: GOP (Various issues Pakistan Meteorological Department).

The following Figure 4.12 portrays average rainfall in the wheat growing season from 1979 to 2009. Violent fluctuations in rainfall in Bahawalpur can be observed in different years.

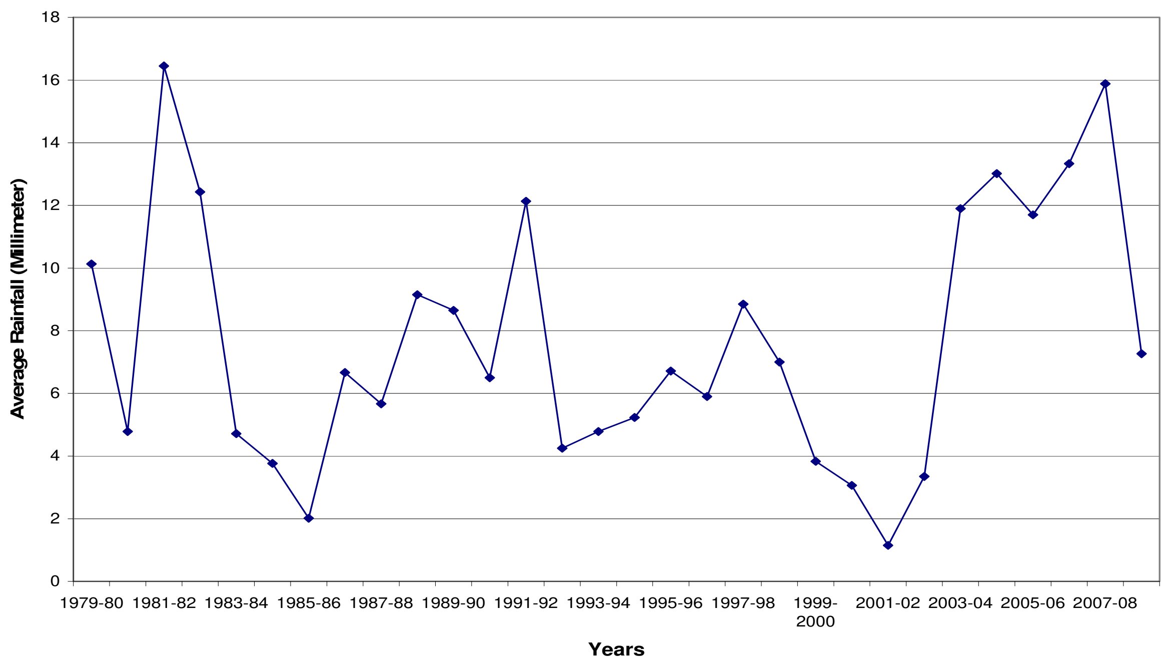

Figure 4.12: Average rainfall in Bahawalpur for wheat growing season from 1979 to 2009

4.2 Regression Analysis

The second part of this chapter deals with the regression analysis. The objective of the thesis was to estimate the wheat yield response to economic, site and climatic variables. The economic variables were proxied by input change, site variable by area change and climate variable by temperature and rainfall. OLS was used to estimate this relationship. In this part firstly data pooling option was checked, secondly multicollinearity and then results of the OLS regression analysis are discussed.

4.3 Data Pooling

Following are the results of the two test used for data pooling i.e., dummy variable test and F-test.

4.3.1 Dummy Variable Test

One of the objectives of this thesis is to compare and contrast the yield responses of farmers in the selected zones of Punjab province. As discussed earlier Faisalabad and Bahawalpur were assumed to be representative of the two zones. But firstly it is necessary to find out whether yield responses in the two representative districts actually differ. The simple arithmetic average of wheat yield is 55.19 mounds per hectare for Faisalabad and 53.32 mounds per hectare for Bahawalpur respectively. These numbers look different, but it is necessary to check whether they are statistically different from one another or not. Dummy variable approach was used for testing this and for similarity of the functional form across the two districts. For this purpose t-test and F-test were used. The model used was:

$$Y_t = \alpha_o + \beta_o D + \beta_1 X_{1t} + \beta_2 X^2_{1t} + \beta_3 X_{2t} + \beta_4 X_{1t} X_{2t} + \beta_5 (D X_{1t}) + \beta_6 (D X^2_{1t}) + \beta_7 (D X_{2t}) + \beta_8 (D X_{1t} X_{2t}) + \mu_t \text{ .... } (4.1)$$

Where

Y= Yield

X_{1t}= Input change

X_{2t}= Area change

t= Time

D= 1 for observations from Bahawalpur

= 0, otherwise (i.e., for observations from Faisalabad)

Following results are obtained from the above model after using pooled data:

Table 4.9: Results of dummy variable test

Variables	*Coefficients*	*t-value*	*P-value*
(Constant)	50.507	19.587	0
input_change	0.501	0.933	0.355
input_change_sq	0.243	2.676	0.01
area_change	0.121	0.335	0.739
input_change_area_change	0.142	1.747	0.087
Dummy	-2.637	-0.724	0.473
dummy_input_change	0.291	0.383	0.703
dummy_input_change_sq	0.047	0.394	0.696
dummy_area_change	0.008	0.02	0.984
dummy_input_change_area_change	-0.18	-1.861	0.069

As these regression results show, both the differential intercept and slope coefficients are statistically insignificant, strongly suggesting that the yield response regressions for the two time periods are same for the two districts, Faisalabad and Bahawalpur.

4.3.2 F-Test for Checking Structural Stability

F-test is used here for checking the stability of the entire regression under the hypothesis that the regressions of Faisalabad and Bahawalpur are similar. And alternate hypothesis is that they are not.

The results of the these models are as following

$$Y_t = \alpha_o + \beta_o D + \beta_1 X_{1t} + \beta_2 X^2_{1t} + \beta_3 X_{2t} + \beta_4 X_{1t} X_{2t} + \beta_5 (D X_{1t}) + \beta_6 (D X^2_{1t}) + \beta_7 (D X_{2t}) + \beta_8 (D X_{1t} X_{2t}) + \mu_{1t} \quad \text{......(4.2)....Unrestricted}$$

$$Y_t = \alpha_o + \beta_1 X_{1t} + \beta_2 X^2_{1t} + \beta_3 X_{2t} + \beta_4 X_{1t} X_{2t} + \mu_{2t} \quad \text{......(4.3)......... Restricted}$$

Table 4.10: Results of F-test analysis

Restricted Model					
Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	2717.47	4	679.367	5.601	0.001
Residual	6428.09	53	121.285		
Total	9145.56	57			
Unrestricted Model					
Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	3355.44	9	372.827	3.091	0.005
Residual	5790.12	48	120.628		
Total	9145.56	57			

So applying the F-test gives following results

$$F_{cal} = \frac{(RSS_R - RSS_{UR})/k}{RSS_{UR}/(n-2k)} \quad \text{.........(4.4)}$$

Putting $RSS_R = 6428.092$, $RSS_{UR} = 5790.120$, n = 58 and k = 2

$F_{cal} = 2.97$ and F_{tab} (α= 5%, n_1= 2 and n_2= 54) = 3.16

Because calculated F-value is less than F-tab the null hypothesis of similar regression is accepted. Thus there is no structural difference in the regressions of Faisalabad and Bahawalpur. Thus the regressions lines for Faisalabad and Bahawalpur are coincident. Thus the data was pooled and same was used instead of estimating separate regressions.

4.4 Multicollinearity Test

Before using the data for determining the wheat yield response function testing of the independent variables for multicollinearity is necessary. Pearson correlation test was used here for the above purpose. Firstly correlation between economic and site variables were calculated. Input change and input change square was used here to represent economic variables and area change and area change square as representing site variable. The interaction of input change and area change was also used. Time trend variable was included to represent technological change over time. For the economic and site variables following results of Pearson correlation test were obtained.

Table 4.11: Results of multicollinearity test

Correlations							
		input_ change	input_ change_sq	area_ change	area_ change_sq	input_change_ area_change	time_ trend
input_change	Pearson Corr.	1	-.072	-.025	-.029	.153	-.021
	Sig. (2-tailed)		.591	.850	.827	.251	.876
input_change_sq	Pearson Corr.	-.072	1	-.037	-.015	-.351**	.173
	Sig. (2-tailed)	.591		.785	.911	.007	.193
area_change	Pearson Corr.	-.025	-.037	1	.582**	.130	.177
	Sig. (2-tailed)	.850	.785		.000	.331	.183
area_change_sq	Pearson Corr.	-.029	-.015	.582**	1	.433**	.221
	Sig. (2-tailed)	.827	.911	.000		.001	.095
input_change_ area_change	Pearson Corr.	.153	-.351**	.130	.433**	1	-.058
	Sig. (2-tailed)	.251	.007	.331	.001		.667
time_trend	Pearson Corr.	-.021	.173	.177	.221	-.058	1
	Sig. (2-tailed)	.876	.193	.183	.095	.667	
** Correlation is significant at the 0.01 level (2-tailed).							

It is clear from the Table 4.11 that there is very high correlation of the area change square variable with both area change and interaction of input change and area change (interaction term). So these cannot be used in the same model. Due to this reason the area change square variable was excluded from the first model containing economic and site variables. There are some other correlations which are significant but they are not too high so these variables were used in the same equation in the analysis.

4.5 Estimation of Wheat Yield Response

After initial data checking the next step is the estimation of yield response. Yield response was estimated step-wise. In the first step yield response to economic and site variables was calculated and in the next step climatic variables were also included in the model. This step-wise procedure has an advantage of seeking differential impact of all these variables, especially the climatic variables (an important area in the wake of global warming and environmental concerns).

4.5.1 Yield Response to Economic and Site Variables

After scrutinizing different modeling possibilities and the way different economic and site variables can be used in the model following model was finalized.

$$Yield = \beta_o + \beta_1\ input\_change + \beta_2\ input\_change\_sq + \beta_3\ area\_change + \beta_4 input\_change\_area\_change + \beta_5\ time\_trend + \mu_t \text{.......}(4.5)$$

All variables are as previously defined. The results of the model were as following:

Table 4.12: ANOVA for Model 4.5

ANOVA					
Model	Sum of Squares	df	Mean Square	F-value	Sig.
Regression	3690.286	5	738.057	7.035	.000
Residual	5455.273	52	104.909		
Total	9145.559	57			
Predictors: (Constant), time_trend, input_change, input_change_area_change, area_change, input_change_sq					
Dependent Variable: Yield (monds/hectare)					

The Table 4.12 shows that the overall model is significant even at 1% level of significance. R^2 for this model was found to be 0.40, a reasonable value for social sciences. The next thing is estimating the regressors and finding the individual significance of these. Following results were obtained and given in Table 4.5.

Table 4.13: Results of Model 4.5

Coefficients				
	B	Std. Error	t-value	Sig.
(Constant)	42.771	2.794	15.309	.000
input_change	0.814	0.344	2.366	.022
input_change_sq	0.209	0.053	3.944	.000
area_change	-0.046	0.151	-0.306	.761
input_change_area_change	0.028	0.040	0.692	.492
time_trend	0.253	0.083	3.045	.004
Dependent Variable: Yield (mounds/hectare)				

The results show that input change, input change square and time trend variable are significant at 5% level of significance. However, area change and interaction term were found insignificant at the above level of significance. From the Table 4.13 the following results were drawn.

The change in input use determined from the profit-maximizing input level condition has a statistically significant positive effect on average yield. Similar positive correlations were also found by some other researchers, for example the positive correlation with input use and corn yield was also found by Kaufmann and Snell (1997) which suggests that changes in relative prices can influence productivity. Reidsma *et al.* (2007) also found crop yield increases with input intensity implying that management strategies can affect the crop yield. While the impact of economic variables was statistically significant, the impact on yield response was relatively small. The small effect is consistent with the finding by Pannell (2006) that the response function for many agricultural inputs is flat around the optimum. The elasticity of yield to input change is low. With 10% increase in input change variable the increase in yield was found to be just 0.12%. This is also consistent with the results obtained by Cabas *et al.* (2009). They also found that 10% increase in input use increases the yield of wheat, corn and soy crops by 0.1%. Krishna (1963) also found that the short and long-run elasticities for economic variables were inelastic.

The term change in input square use is positive and is significant at 1% significance level. With 10% increase in input change square variable the yield increases by 0.63%. The elasticity is higher as compared to input change. As the quadratic term on the change in input use is positive and statistically significant in this model it suggest the existence of increasing marginal returns to inputs on crop yield. This might look very odd keeping in mind the usual economic focus on diminishing marginal returns. But this is positive in case of selected sample and thus for Punjab because the level of input use is not at recommended level. It means that inputs are being used less than as recommended for the optimum production of wheat. This also suggests that there is very obvious possibility of increasing wheat yield by increasing the level of input use. Another important point that can be made here is that either the farmers are unaware of the level of optimum input use or they have lack of finance for the purchase of inputs.

An increase in area planted to a crop was assumed to decrease average yield since more marginal land is brought into production and the result is as expected. This is because most productive lands are always under cultivation especially in Punjab and area increase means bringing more marginal land under cultivation. The negative coefficient of area change implies that with increase in the area change (usually area increase) the wheat yield actually decreases. But the area change coefficient is statistically insignificant pointing to the fact that its impact has not been too much. This is not surprising because it becomes clearer by looking at the area trend under wheat cultivation and yield over time. While wheat yield has increased from 33.6 mounds per hectare to 84.2 mounds per hectare in the period 1980-2009 the area under wheat has not increased too much, in fact it increased from 178.8 thousand hectares to 289.9 thousand hectares. Thus it is evident from the above statistics that increase in wheat yield is less associated to area change and more to other variables, as suggested by the above model.

The interaction term between the change in planted area and the change in input use is also statistically insignificant and positive as expected for wheat yield response. The result suggests that increases in the area of less productive land planted to a crop can still result in increases in yield provided additional inputs are used. The positive value of interaction term and its insignificance suggest that yield response is positive to combine increase in area and input use but due to less awareness or lack of finance, as discussed above, farmers cannot respond to less productive lands with high input use resulting in very less yield response to these variables combine.

Technological advances as captured by time trend variable also increased average yield as expected. The coefficient indicates the increase in yield in mounds per hectare expected annually and the values are consistent with the trends in yields discussed earlier. Overtime yield has increased significantly. Technological advances such as increase in modern input use and their level of use were already captured by input change and input change square variable resulting in lower than expected value of the time trend variable coefficient. The rest of the changes such as improved management etc. are captured here with time trend variable. This variable tells that each year the wheat yield has increased by 0.13 mounds per hectare just due to factors other than fertilizer and other input use changes. This change is significant even at 1% level of significance.

As the coefficients of the economic and site variables are generally small the impact on yield distribution is also relatively small. The relatively small effects of the non-climatic variables aside suggest that climatic variables should have a major effect on yield distribution.

4.5.2 Yield Response to Climatic Variables

To check the separate impact of climatic variables on wheat yield separate model was run. After going through all the process of model estimation, as discussed in research methodology, following model was considered most appropriate for yield response to climatic variables.

$$Y_t=\beta_o+\beta_1\, temp\_max\_maturity+\beta_2\, temp\_\, min\_sowing + \beta_3\, rainfall\_avg+\beta_4\, rainfall\_cov \ldots\ldots(4.6)$$

Where rainfall_avg is average rainfall and rainfall_cov is rainfall covariance. OLS estimation of the above model gives following results.

Table 4.14: ANOVA for Model 4.6

ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	4794.702	4	1198.675	14.602	.000
Residual	4350.858	53	82.092		
Total	9145.559	57			
Predictors: (Constant), rainfall_cov, rainfall_avg, temp_min_sowing, temp_max_maturity					
Dependent Variable: Yield (monds/hectare)					

Table 4.14 shows that the estimated model is significant even at 1% level of significance proving it an appropriate model. R^2 value for this model was found 0.524, thus a good fit model. Having good overall fitness of the model the last step is to check individual significance of the variables through t-test. The results are as following:

Table 4.15: Result of Model 4.6

Coefficients				
	B	Std. Error	t-value	Sig.
(Constant)	-75.687	26.549	-2.851	.006
temp_max_maturity	2.977	0.788	3.777	.000
temp_min_sowing	3.423	0.628	5.452	.000
Rainfall_avg	0.115	0.203	0.567	.573
Rainfall_cov	-0.202	0.073	-2.760	.008
Dependent Variable: Yield (monds/hectare)				

It can be observed from Table 4.15 that maximum temperature at maturity stage of wheat crop (average of March and April), minimum temperature at sowing stage (November and December) and rainfall covariance are significant and rainfall average (average of all growing season of wheat) is insignificant. Following inference can be drawn from the above model results.

The impact of maximum temperature at maturity stage was found significant at 1% level of significance. The value is positive and significant having a value of 2.98. It means that with each one Celsius increase in maximum temperature at maturity stage wheat yield increases by approximately 3 mounds per hectare holding all other variables constant. This is because higher temperature at the maturity stage helps the crop to mature and be harvested with less field losses. The result obtained in this model are in line with the results of Weber and Hauer (2003) and Mendelsohn and Reinsborough (2007) both estimated that Canadian farmland values increase with temperature and precipitation.

Yield response to minimum temperature at sowing stage was significant at 1% level of significance. The value is more positive than that of maximum temperature at maturity stage meaning that it had more impact on wheat yield than it. It can be inferred from the Table 4.15 that with each one degree Celsius increase in minimum temperature at sowing stage (months of November and December) the wheat yield increase by 3.4 mounds per hectare. This is because increase in minimum temperature at sowing stage make it possible to plant the crop sufficiently and it helps in proper germination of the wheat seed and thus higher expected yield. The result was as expected and quoted in the literature.

The yield response to average rainfall (average of all six months of growing season of wheat) was positive, as expected, but insignificant. With the increase in average rainfall the wheat yield increases but the affect is not significant. This may be because rainfall has more positive affect on crop yield when combined with other agricultural inputs. Such as, in the time of water stress the applications of other inputs do not have more positive affect on yield. So if rainfall is coupled with other inputs such as timely application of fertilizer results in higher yield response of wheat to both rainfall and fertilizer. The affect of rainfall was also found to be significant on sugarcane yield by Chaudhry and Chaudhry (1990).

Variability in precipitation is expected to have an inverse affect on wheat yield. An increase in the rainfall covariance represents an increase in the proportionate variability of rainfall and it is assumed to decrease the level of crop yields and increase yield variation. The above model show that there is negative relationship, as expected, between wheat yield and rainfall covariance and the effect is highly significant (significant at 1% level of significance). This means that with increase in rainfall variation the wheat yield decreases. With each one unit change in rainfall covariance the wheat yield reduces by 0.2 mounds per hectare. The result is same as obtained by Cabas *et al.* (2009), they also found that the impact of rainfall covariance (Precipitation CV in their model) is negative on wheat yield.

4.5.3 Yield Response to Economic, Location and Climatic Variables

Analysis of the separate response of economic and site variables and of climatic variables on wheat yield resulted in above outcomes. Now the next step is the estimation of wheat yield response to economic, site and climatic variables together. As discussed in research methodology two models could have represented the wheat yield response to all the desired variables included in this research study. The first model used was a simple combination of the separate economic and site model and climate impact model. The second model was selected after considering the importance of separate variables and their correlation with each other and with yield.

The first model was

$$Y_t=\beta_o+\beta_1 input\_change+\beta_2 input\_change\_sq+\beta_3 area\_change+\beta_4 input\_change\_ area\_change+\beta_5 time\_trend+\beta_6 temp\_max\_maturity+\beta_7\, temp\_\, min\_sowing + \beta_8\, rainfall\_avg+ \beta_9\, rainfall\_cov + \mu_t \text{ ……..(4.7)}$$

The model was estimated through ordinary least square. The analysis of variance (ANOVA) technique was applied for the overall significance of the model. ANOVA Table is presented below.

Table 4.16: ANOVA for Model 4.7

ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	7219.118	9	802.124	19.986	.000
Residual	1926.441	48	40.134		
Total	9145.559	57			
Predictors: (Constant), rainfall_cov, input_change, input_change_area_change, area_change, input_change_sq, rainfall_avg, temp_max_maturity, temp_min_sowing, time_trend					
Dependent Variable: Yield (monds/hectare)					

The Table 4.16 shows that the overall model is significant, as represented by highly significant F-value at 1% level of significance. R square value for this model was 0.789 (approximately 79%) proving that overall fitness of the model is also good. Checking the individual significance of the variables gives the results presented below:

Table 4.17: Results of Model 4.7

Coefficients				
	B	Std. Error	t-value	Sig.
(Constant)	-60.353	18.907	-3.192	.002
input_change	0.700	0.219	3.190	.003
input_change_sq	0.070	0.037	1.904	.063
area_change	0.026	0.095	0.280	.781
input_change_area_change	-0.002	0.027	-0.090	.929
time_trend	0.674	0.109	6.156	.000
temp_max_maturity	1.360	0.603	2.255	.029
temp_min_sowing	3.858	0.508	7.590	.000
Rainfall_avg	0.198	0.163	1.215	.230
Rainfall_cov	0.070	0.064	1.091	.281
Dependent Variable: Yield (mounds/hectare)				

The interpretation of all the variables are the same as explained above. So these will be discussed in brief.

The yield response of wheat to input change in aggregated model is the same positive and significant. With increase in input change the yield increases. The yield response to input change is positive and increasing as represented by positive coefficient of input change square. Although the impact of input change was less in this model than the model containing individual impact of economic and site variables but the rate of yield increase with input increase was more here. This may be because with more favorable minimum sowing temperature, maximum maturity period, average rainfall and covariance of rainfall the rate of wheat yield increase must be higher, as was the finding of this model. This result is also theoretically strong because at the time of sowing the application of fertilizer result in higher yields if minimum temperature, significant in this model, is suitable for proper germination of the seed. Wheat yield increases at increasing rate again pointing out that the level of input use is very low in Punjab which results in lower than potential yield of wheat. As pointed out earlier that in terms of wheat yield Pakistan is far behind other Asian counterparts as well as overall wheat producing world. Thus using inputs more intensively to achieve food self sufficiency and more importantly for food security is a good option.

Strikingly the impact of area change has changed, its impact is positive on wheat yield. Though it is insignificant but it indicates an important point, i.e., with some favorable climatic factors and input application at some proper fixed level the yield response to area change can be positive. But the interaction term was negative in this model indicating that with increases in area change and input change combine and incorporating the environmental (climatic) factors into the model result in overall negative influence on the wheat yield. It may be because marginal lands, which will come under cultivation with area increase, are already less responsive to more input application when combined with environmental severities will obviously result in lower wheat yield levels.

Time trend variable had a positive and significant affect on wheat yield, as earlier. But it is now more positive than impact in yield response function having economic and site variables alone. This result was in line with the reasoning previously discussed in the time trend effect. It is important to note that as the impact of input change variable increases the affect of time trend variable decrease because more of the variation in wheat yield is explained by the input change variable the less is left for other technological variables to explain. Holding input change variables, area change variable, interaction term and climatic variables constant each year wheat yield increases by 0.67 mounds per hectare.

The impact of economic and site variables had been less in this model which suggests that the impact of climatic variables will be higher. Looking at the results above perception proves right. Mean maximum temperature at maturity stage had a positive and significant effect on wheat yield. It is positive and is significant at 5% level of significance. With each one degree Celsius increase in mean maximum temperature during the months of March and April increases the wheat yield by 1.36 mounds per hectare. The impact is higher than all other economic and site variables may be because it helps in proper maturity of the crop.

Mean minimum temperature at sowing stage (months of November and December) had the greatest affect, out of all economic, site and climatic variables, on wheat yield. Its impact was found positive and highly significant, i.e., significant at 1% level of significance. Analysis shows that with each one degree Celsius increase in mean maximum temperature the wheat yield increases by 3.86 mounds per hectare. Such a high relation is justified because with increase in minimum temperature wheat seed germination increases resulting, off course, in higher yield.

The impact of average rainfall and rainfall covariance was found be positive but insignificant. With increase in rainfall wheat yield increases but the yield increase must be very small leading to insignificance of this variable. Pearson correlation matrix shows that mean minimum temperature at sowing stage was highly correlated with average rainfall and rainfall covariance. Thus in order to see the wheat yield response to rainfall mean minimum temperature must be dropped from the model. Ayub *et al.* (1974) and Griffiths *et al*. (1999) also concluded that the choice between actual rainfall and the deviations from normal rainfall was a matter for empirical investigation and their results were not robust. Thus another model was developed as explained below.

General representation of the second model is as following:

$$Y_t=\beta_o+\beta_1 input\_change+\beta_2 input\_change\_sq+\beta_3 area\_change+\beta_4 input\_change\_area\_change+\beta_5 time\_trend+\beta_6 temp\_max\_maturity+\beta_7\, rainfall\_avg + \mu_t \quad \ldots\ldots(4.8)$$

OLS estimation of the above wheat yield response to economic, site and climatic variables had given following results.

Table 4.18: ANOVA for Model 4.8

ANOVA					
Model	Sum of Squares	df	Mean Square	F-value	Sig.
Regression	4334.019	7	619.146	6.434	.000
Residual	4811.541	50	96.231		
Total	9145.559	57			
Predictors: (Constant), rainfall_avg, area_change, input_change, input_change_sq, temp_max_maturity, input_change_area_change, time_trend					
Dependent Variable: Yield (monds/hectare)					

It is evident from the Table 4.18 that the overall model is highly significant, i.e., at 1% level of significance. R square value was calculated as 0.474. Thus the overall model is appropriate. The overall fitness of the model does not guarantee good results as well because individual variables' significance is also very important. For this task Table 4.19 was developed.

Table 4.19: Results of Model 4.8

Coefficients				
	B	Std. Error	t-value	Sig.
(Constant)	-9.918	22.494	-0.441	.661
input_change	0.880	0.336	2.616	.012
input_change_sq	0.186	0.052	3.559	.001
area_change	-0.077	0.145	-0.533	.597
input_change_area_change	0.054	0.041	1.334	.188
time_trend	0.207	0.106	1.960	.056
temp_max_maturity	1.416	0.659	2.149	.036
rainfall_avg	0.428	0.235	1.817	.075
Dependent Variable: Yield (monds/hectare)				

From the above Table 4.19 it can be deduced that most of the variables are statistically significant. Their explanation is as following:

Wheat yield response to input change variable was positive and was highly significant at 1% level of significance. With one unit increase in input change the wheat yield increases by 0.88 mounds per hectare. This effect is more than that of the model when climatic variables were not included in the model. It clearly means that input change variable increases yield significantly but when combined with optimum climatic variables it multiplies the affect of economic variables. Overall the affect of input change variable has been less. This is the similar result as obtained by Choi and Helmberger (1993). They found that the affect of price incentives (economic variables) to wheat, corn and soybean yield is quite inelastic.

The rate of change of yield increases with increase in input change. This rate of change is positive and highly significant. With the addition of affect of rainfall variable in this model the responsiveness of wheat yield to input change variable has increased as compared to the previous model.

Area change was found to be having negative impact on wheat yield as it should be but it is insignificant. The reasoning behind this is the same as discussed in the above discussion under the model of yield response to economic and site variable. The interaction term, between input change and area change, is positive but insignificant.

The time trend variable affect yield positively and this effect is significant at 10% level of significance. This model suggest that each year yield increases by 0.2 mounds per acre keeping all other economic, site and climatic variables at given fixed level. Due to aforementioned reasons the impact of time trend is less than that of the previous model.

Mean maximum temperature at maturity stage (average of March and April) has positive and significant affect on wheat yield, as suggested by the above Table 4.19. Its value is significant at 5% level of significance. The model predicted that each one unit increase in mean maximum temperature at maturity increases the wheat yield by 1.4 mounds per hectare. The impact of this variable is highest on yield as compared to all other economic, site and climatic variables. This impact is higher than that of the previous model most probably due to the inclusion of affect of rainfall variable in the model. Knight *et al*. (1978) also concluded that higher maximum temperature is associated with higher wheat yields in Alaska while lower maximum temperature leads to lower yields.

Wheat yield response to average rainfall is positive and is significant at 10% level of significance. Wheat yield increases by 0.4 mounds per hectare with each one millimeter increase in average rainfall in Punjab holding all other variables constant. Khan *et al.* (2003) also found that the estimated coefficient of water for wheat was highly significant and shows that 1 percent increase in water availability increases the wheat production by 0.6838 percent. This impact is very important in the wake of growing shortage of water and less rainfall years at proper time of wheat cultivation. It is important to mention here that this impact of average rainfall might have increased significantly when combined with other input variables.

Results of Wald Test

Null Hypothesis: $C(1)=C(2)=C(3)=C(4)=C(5)=C(6)=C(7)=C(8)=C(9)=0$

Alternate Hypothesis: $C(1)=C(2)=C(3)=C(4)=C(5)=C(6)=C(7)=C(8)=C(9)\neq 0$

F-statistic 6.43 Probability 0.00

Chi-square 45.04 Probability 0.00

Thus based on the above statistic the null hypothesis is rejected and the viability of the model is held satisfactory.

CHAPTER-5

SUMMARY

This study was carried out to estimate the wheat yield response function. The explanatory variables were economic, location and climatic variables. The proxy variable for economic variable was input change, for location variable it was area change and for climatic variables these were temperature and rainfall. The method of Ordinary Least Square was used to draw the wheat yield response function.

As a first step of model specification the possibility of any structural difference in the regression of two districts, Faisalabad and Bahawalpur was checked. If there exists some structural difference in the two districts separate model should be developed for estimating the wheat yield response function. But if there would be no difference in them the data can be pooled and used as a single entity. The results of the two tests showed that the regression of the two districts was same and thus was used as one unit.

The thesis is on estimating the supply response functions of wheat in two agro-climatic zones of Punjab, because Punjab, currently, alone contributes approximately 76.64% to the total wheat production and area. So Punjab was selected for analysis due to its major share in wheat production and area. For the purpose of current analyses two agro-ecological zones, namely mixed zone and cotton-wheat zone, were selected as representative of all wheat growing areas of Punjab. These two zones, combine, contribute 68.4% to total wheat production in the country. Faisalabad and Bahawalpur districts were selected from these two zones because they account for largest share in the total area of the Punjab in terms of wheat area. Faisalabad covers 4.15 percent while Bahawalpur covers 4.33 percent of the total wheat area; both are larger than all districts from Punjab.

Main Findings

- Over the last 30 years the area in Faisalabad increased by 2% from 267 thousand hectares to just 272.65 thousand hectares from 1979 to 2009 while yield increased above 109% in the study period. The production and yield of wheat has increased

- In Bahawalpur area has increased from 174.6 thousand hectares to 282.4 thousand hectares from 1979 to 2009 increasing by around 62% in 30 years while yield has increased around 124% in this period. Production has increased much more than that of area in Bahawalpur, virtually above 200% more, production increase has been 262% from 1979 to 2009.
- The average maximum temperature in Faisalabad has increased by almost 1.5^{o}C in the previous 30 years.
- The tests for data pooling, dummy variable test and F-test, told that the regression in Faisalabad and Bahawalpur is coincident. Thus the data was pooled and used as a single entity.
- Wheat yield response is relatively flat towards economic and location variables.
- Economic incentives increase wheat yield at increasing rate which means the farmers in the study area are operating in the first stage of production function and thus yield can be increased by giving incentives to use more inputs to come at optimum level.
- Area response to yield is negative i.e., yield actually decreases due to increase in area because most of the area increase means bringing more marginal area under cultivation.
- OLS estimation of the wheat yield response concludes that the impact of climatic variables is highest.
- Mean maximum temperature at maturity stage of wheat production increases wheat yield with its increase and this affect is highest as compared to all other economic, location and climatic variables.
- Average rainfall, of wheat growing season, has positive affect on wheat yield. This is particularly important in view of growing water shortage in the country.

Policy Recommendations

- Vertical expansion has a greater scope in Punjab. Punjab is major supplier of wheat, 76% of total, which means that the yield increase by means of more intensive use of inputs using the same area under cultivation Pakistan still has an opportunity to feed its future generations by utilizing domestic resources.
- Horizontal expansion is not the solution to meet our food security needs. Increase in area under wheat does not much due to several reasons including less than optimal use of inputs and lower yield response to inputs and area. More marginal lands will producer lesser in terms of yield and, thus, are not appropriate solution for growing food insecurity in the country.
- Proper farm management and technology adoption are also important factors in increasing yield. One of the reasons for less than optimal input use may be lack of proper awareness of it. Thus there should be training programmes for the farmers by the extension staff.
- Timely availability of inputs at reasonable prices should be ensured because it is also determining factor in yield. Even if it is assumed that farmers have knowledge of proper input use the lack of inputs at right time hinders the true yield potential.
- Wheat varieties should be developed which are more adaptive to changing climatic conditions. Climate change will also be determining factor in future yield responses because of its highest influence on the wheat yield response, as determined in this study.
- Water shortage in Punjab is critical so improvement in water availability and its use should be of high priority.

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APPENDICES

Appendix 1: Monthly prices of wheat in Faisalabad

(Prices In Rs. Per 100 Kg)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
1980-81	147	146	144	149	146	146	146	147	150	165	175	177	153.17
1981-82	178	178	177	169	153	152	155	164	172	175	177	182	169.33
1982-83	183	183	181	178	165	166	169	178	176	180	190	188	178.08
1983-84	189	190	206	188	165	174	178	183	191	199	202	210	189.58
1984-85	211	214	215	210	184	197	203	209	214	208	217	218	208.33
1985-86	221	221	216	209	203	205	207	201	203	207	212	218	210.25
1986-87	218	215	222	204	202	209	205	197	198	210	225	227	211
1987-88	228	225	219	219	209	222	236	237	237	234	229	230	227.08
1988-89	235	237	253	245	219	224	233	251	257	259	259	261	244.42
1989-90	264	262	253	248	238	248	262	282	288	290	293	295	268.58
1990-91	304	311	305	312	296	300	333	332	337	341	354	354	323.25
1991-92	355	386	371	347	337	357	364	368	346	347	358	364	358.33
1992-93	368	365	365	365	340	345	370	385	388	388	388	388	371.25
1993-94	390	410	485	450	420	433	448	470	478	475	485	495	453.25
1994-95	468	493	485	483	440	435	450	453	455	453	458	468	461.75
1995-96	465	473	483	463	460	463	469	455	515	518	562	573	491.58
1996-97	643	678	698	778	658	695	698	708	710	712	720	730	702.33
1997-98	731	725	700	672	647	696	706	729	631	612	644	683	681.33
1998-99	717	742	800	707	683	667	644	661	672	706	722	739	705
1999-2000	738	742	757	763	757	749	737	743	793	805	851	847	773.5
2000-01	838	853	850	797	716	692	662	691	729	761	787	737	759.42
2001-02	804	817	819	761	712	743	762	773	817	834	838	850	794.17
2002-03	862	881	882	797	761	801	822	851	862	893	975	1054	870.08
2003-04	1006	1029	1082	922	968	982	1038	1048	1042	1075	1150	1146	1040.67
2004-05	1125	1145	1121	1081	1026	1082	1088	1045	1051	1053	1091	1108	1084.67
2005-06	1137	1134	1107	1089	1037	1019	1062	1108	1122	1122	1116	1133	1098.83
2006-07	1138	1138	1190	1141	1071	1090	1185	1210	1323	1325	1412	1425	1220.67
2007-08	1450	1427	1417	1558	1683	1736	1744	1757	1795	2117	2188	2150	1751.83
2008-09	2205	2195	2196	2313	2344	2305	2346	2403	2413	2481	2542	2568	2359.25

Sources: Directorate of Agriculture (Economics & Marketing), Agriculture Department, Lahore.

Appendix 2: Monthly prices of wheat in Bahawalpur

(Prices In Rs. Per 100 Kg)													
Years	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual Average**
1980-81	144	143	140	142	142	142	146	147	148	159	171	175	149.92
1981-82	179	179	179	176	153	152	154	161	166	171	174	179	168.58
1982-83	180	181	178	176	166	165	167	170	171	176	185	186	175.08
1983-84	191	195	199	191	168	171	176	181	189	197	202	209	189.08
1984-85	210	217	219	206	180	189	189	185	191	195	204	208	199.42
1985-86	222	226	216	205	203	203	203	203	199	200	203	212	207.92
1986-87	219	218	209	204	200	206	202	201	199	198	198	220	206.17
1987-88	225	219	217	219	215	220	232	223	225	225	223	223	222.17
1988-89	227	229	223	240	216	217	220	239	250	255	263	265	237
1989-90	258	255	246	246	242	247	254	269	277	277	280	291	261.83
1990-91	298	295	292	290	290	302	317	324	330	331	343	347	313.25
1991-92	351	363	361	352	332	344	359	364	353	353	353	356	353.42
1992-93	356	357	359	355	336	342	358	369	371	375	376	383	361.42
1993-94	386	402	439	442	417	429	443	456	470	482	496	495	446.42
1994-95	487	484	476	475	428	432	448	459	455	447	452	457	458.33
1995-96	462	472	475	474	459	464	470	475	499	511	547	562	489.17
1996-97	623	673	613	723	646	682	699	706	715	728	737	734	689.92
1997-98	745	742	720	687	634	659	682	706	644	629	642	687	681.42
1998-99	724	736	768	668	647	652	638	643	664	687	709	735	689.25
1999-2000	740	740	749	746	745	731	731	731	785	812	829	842	765.08
2000-01	851	853	853	802	707	686	649	684	717	751	788	753	757.83
2001-02	794	808	813	753	699	740	760	773	814	824	839	847	788.67
2002-03	851	881	890	799	759	797	821	850	863	893	977	1055	869.67
2003-04	1016	1042	1085	913	951	973	1026	1035	1034	1064	1147	1150	1036.33
2004-05	1127	1145	1140	1082	1044	1078	1093	1072	1064	1065	1092	1101	1091.92
2005-06	1128	1134	1120	1067	1032	1040	1060	1092	1100	1109	1125	1136	1095.25
2006-07	1153	1170	1174	1119	1080	1119	1167	1188	1314	1361	1445	1554	1237
2007-08	1686	1582	1551	1631	1732	1771	1795	1888	1813	2108	2060	2069	1807.17
2008-09	2200	2157	2257	2233	2300	2262	2328	2384	2404	2455	2494	2603	2339.75

Sources: Directorate of Agriculture (Economics & Marketing), Agriculture Department, Lahore.

Appendix 3: Input change for Faisalabad district

			Prices					
Years	FSD prices of wheat	FSD wheat yield	Electricity	Urea	DAP	HSD	AVG input prices	Input change
1979-80	66.72	33.07	22.3	93	100	2.93	218.23	
1980-81	61.26	34.51	23	93	100	3.12	219.12	0.441
1981-82	67.73	35.96	23	115	113	3.45	254.45	0.348
1982-83	71.23	37.42	23	128	133	4	288	0.342
1983-84	75.83	38.88	23	128	133	4.25	288.25	0.361
1984-85	83.33	40.36	25	128	133	4.25	290.25	0.384
1985-86	84.1	41.84	25	128	146	4.01	303.01	0.407
1986-87	84.4	39.16	29	130	146	3.91	308.91	-0.729
1987-88	90.83	42.99	35	135	161	3.85	334.85	0.964
1988-89	97.76	54.94	42	165	185	3.85	395.85	2.743
1989-90	107.43	48.67	45	185	217	4.64	451.64	-1.357
1990-91	129.3	46.35	49	195	249	5.05	498.05	-0.500
1991-92	143.33	52.71	49	195	272	5.5	521.5	1.576
1992-93	148.5	48.47	49	205	264	5.75	523.75	-1.159
1993-94	181.3	54.81	49	210.1	269	6.12	534.22	1.760
1994-95	184.7	59.46	49	235	379	6.52	669.52	1.261
1995-96	196.63	53.72	49	267	479	7.87	802.87	-1.321
1996-97	280.93	61.17	49	340	553	9.86	951.86	1.538
1997-98	272.53	58.24	49	344	574	9.66	976.66	-0.840
1998-99	282	61.88	49	346	665	10.37	1070.37	0.926
1999-2000	309.4	63.49	49	327	649	14.64	1039.64	0.435
2000-01	303.76	73.15	76	363	669	16.86	1124.86	2.656
2001-02	317.66	65.18	90	394	710	18.11	1212.11	-1.997
2002-03	348.03	70.50	90	411	765	21.69	1287.69	1.313
2003-04	416.26	74.45	90	421	913	24.2	1448.2	0.949
2004-05	433.86	57.16	90	468	1001	31.57	1590.57	-4.524
2005-06	439.53	72.53	90	509	1079	38.21	1716.21	3.885
2006-07	488.26	77.55	90	527	993	37.78	1647.78	1.339
2007-08	700.73	65.59	379	581	1934	53.62	2947.62	-1.980
2008-09	943.7	69.28	424	744	2787	58.86	4013.86	0.644

Source: 1) Directorate of Agriculture (Economics & Marketing), Agriculture Department, Lahore.
2) Economic Survey of Pakistan (various issues)
3) Author own calculation

Appendix 4: Input change for Bahawalpur district

			Prices					
Years	BWP prices of wheat	BWP wheat yield	Electricity	Urea	DAP	HSD	AVG input prices	Input change
1979-80	70.36	31.76	22.3	93	100	2.93	218.23	
1980-81	59.97	33.594	23	93	100	3.12	219.12	0.589
1981-82	67.43	35.338	23	115	113	3.45	254.45	0.411
1982-83	70.03	37.004	23	128	133	4	288	0.390
1983-84	75.63	38.598	23	128	133	4.25	288.25	0.387
1984-85	79.77	40.124	25	128	133	4.25	290.25	0.398
1985-86	83.17	41.587	25	128	146	4.01	303.01	0.385
1986-87	82.47	43.731	29	130	146	3.91	308.91	0.577
1987-88	88.87	42.739	35	135	161	3.85	334.85	-0.244
1988-89	94.8	49.254	42	165	185	3.85	395.85	1.463
1989-90	104.73	44.406	45	185	217	4.64	451.64	-1.018
1990-91	125.3	44.145	49	195	249	5.05	498.05	-0.055
1991-92	141.37	51.343	49	195	272	5.5	521.5	1.729
1992-93	144.57	55.447	49	205	264	5.75	523.75	1.108
1993-94	178.57	47.544	49	210.1	269	6.12	534.22	-2.139
1994-95	183.33	52.143	49	235	379	6.52	669.52	1.227
1995-96	195.67	49.148	49	267	479	7.87	802.87	-0.684
1996-97	275.97	59.424	49	340	553	9.86	951.86	2.112
1997-98	272.57	54.794	49	344	574	9.66	976.66	-1.308
1998-99	275.7	56.232	49	346	665	10.37	1070.37	0.366
1999-2000	306.03	57.104	49	327	649	14.64	1039.64	0.231
2000-01	303.13	61.003	76	363	669	16.86	1124.86	1.061
2001-02	315.47	59.12	90	394	710	18.11	1212.11	-0.471
2002-03	347.87	67.379	90	411	765	21.69	1287.69	2.023
2003-04	414.53	84.179	90	421	913	24.2	1448.2	4.036
2004-05	436.77	67.946	90	468	1001	31.57	1590.57	-4.231
2005-06	438.1	64.635	90	509	1079	38.21	1716.21	-0.843
2006-07	494.8	72.809	90	527	993	37.78	1647.78	2.173
2007-08	722.87	64.486	379	581	1934	53.62	2947.62	-1.397
2008-09	935.9	71.163	424	744	2787	58.86	4013.86	1.202

Source: 1) Directorate of Agriculture (Economics & Marketing), Agriculture Department, Lahore.
2) Economic Survey of Pakistan (various issues)
3) Author own calculation

Appendix 5: Economic and location variables of Faisalabad

Year	Input change	Input change square	Area change	Input change* Area change
1980-81	1.096	1.201	-0.745	-0.817
1981-82	0.872	0.760	-0.745	-0.649
1982-83	0.856	0.733	-0.745	-0.638
1983-84	0.905	0.818	-0.745	-0.674
1984-85	0.962	0.925	-0.745	-0.717
1985-86	1.018	1.037	-0.745	-0.759
1986-87	-1.823	3.324	3.248	-5.922
1987-88	2.412	5.819	-9.300	-22.435
1988-89	6.859	47.043	0.900	6.173
1989-90	-3.394	11.521	2.800	-9.504
1990-91	-1.251	1.565	-1.600	2.002
1991-92	3.940	15.525	1.600	6.304
1992-93	-2.899	8.402	-6.100	17.681
1993-94	4.403	19.384	3.300	14.529
1994-95	3.154	9.945	2.800	8.830
1995-96	-3.304	10.913	0.400	-1.321
1996-97	3.846	14.792	-5.600	-21.537
1997-98	-2.102	4.419	-8.500	17.867
1998-99	2.315	5.360	6.365	14.736
1999-2000	1.089	1.186	-0.745	-0.811
2000-01	6.642	44.121	10.080	66.955
2001-02	-4.994	24.940	-12.100	60.428
2002-03	3.283	10.775	4.000	13.130
2003-04	2.374	5.638	11.000	26.119
2004-05	-11.311	127.935	11.700	-132.337
2005-06	9.713	94.333	-3.200	-31.080
2006-07	3.348	11.208	-10.100	-33.813
2007-08	-4.952	24.526	2.400	-11.886
2008-09	1.611	2.596	6.750	10.876

Source: Author own calculation

Appendix 6: Economic and location variables of Bahawalpur

Year	Input change	Input change square	Area change	Input change* Area change
1980-81	1.391	1.935	4.200	5.842
1981-82	1.028	1.056	4.100	4.213
1982-83	0.975	0.951	4.200	4.097
1983-84	0.968	0.937	4.200	4.066
1984-85	0.994	0.988	4.100	4.076
1985-86	0.962	0.926	4.200	4.042
1986-87	1.443	2.083	3.600	5.196
1987-88	-0.611	0.373	-3.300	2.016
1988-89	3.656	13.370	15.400	56.310
1989-90	-2.544	6.471	1.200	-3.053
1990-91	-0.137	0.019	5.300	-0.726
1991-92	4.323	18.690	-8.100	-35.018
1992-93	2.769	7.669	42.100	116.585
1993-94	-5.347	28.586	-21.500	114.951
1994-95	3.066	9.403	-5.700	-17.479
1995-96	-1.710	2.924	15.000	-25.647
1996-97	5.281	27.893	-9.300	-49.117
1997-98	-3.271	10.697	18.200	-59.525
1998-99	0.915	0.837	1.200	1.098
1999-2000	0.578	0.334	4.100	2.370
2000-01	2.652	7.034	14.100	37.396
2001-02	-1.177	1.386	-2.000	2.355
2002-03	5.059	25.590	-1.200	-6.070
2003-04	10.089	101.781	-0.800	-8.071
2004-05	-10.576	111.861	3.600	-38.075
2005-06	-2.107	4.440	18.400	-38.771
2006-07	5.433	29.520	-10.700	-58.136
2007-08	-3.493	12.199	-2.400	8.383
2008-09	3.006	9.038	5.600	16.836

Source: Author own calculation