A comparison of input resource use and production efficiency of wheat between China and Pakistan using Stochastic Frontier Analysis (SFA)

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Abstract

The efficient usage of input resources, and adoption of modern technology strengthen the agricultural productivity and efficiency. The present study aims to compare the inputs usage and production efficiency of wheat in China and Pakistan. The wheat production efficiency was estimated by using wheat farm level primary data from district Kambar Shahdadkot in Sindh province in Pakistan and district Bozhou in Anhui province China. The survey was used to residents of 21 villages in Kambar Shahdadkot and 22 villages in BoZhou. A total of 120 wheat farmers were randomly interviewed for the case of both countries. To analyses the wheat production efficiency by using stochastic frontier analysis (SFA) model a set input and output parameters are used as, the output parameter of wheat farm productivity, input parameters as wheat farmland, wheat seeds, fertilizer, farmyard manure, pesticides, labor, and machinery used. For the estimation of technical inefficiency of a household the parameters such as wheat farmer age, education and farming experience were used. The results of estimated Maximum likelihood estimates (MLE) shows the wheat farm size, and farming experience of wheat farmers in both countries are the major favorable component of wheat production in both countries. However, the wheat seed and more use of machinery in wheat farms are a positive factors of China's wheat production over wheat farm production of Pakistan. The result shows the 26.67 percent of wheat farms have the highest production efficiency in Pakistan, However, in China, more farms about 33.33 percent have the highest wheat farm production efficiency. Study concluded that China have highest wheat farm production efficiency comparing to Pakistan, due to adoption of modern seed technology and high use of modern machinery and proper usage of input resources.

Keywords: China. Pakistan. Production Efficiency. Wheat.

1. Introduction

Wheat (*Triticum aestivum* L.) is very important cereal grain crop and staple food in many countries of the world, (Abbas *et al.* 2017). It contributes to the main source of the 70 percent of the population of the world (Radosavac and Knežević 2017). It is a major sources of rural agricultural income and playing a main source food security, and occupies a central position agricultural productivity in China and Pakistan (Chuan *et al.* 2016; Memon *et al.* 2015). China is the world's largest wheat producing country, it produces 17 percent of the world's wheat production in 11 percent of the world's wheat planting area in 2014-15 (USDA 2016).

Wheat production comprises 21.1 percent of total food grain production and placed a remarkable position in total agricultural productivity in China (Lv *et al.* 2017). Wheat is the major crop contributing food security in Pakistan, about 72% of the protein and 42% of calories full filled in daily diet by wheat in countries population in Pakistan (GOP 2008). It is the staple food grain crop, it contributes about 9.1 percent in agricultural value added and 1.7 percent in total GDP in Pakistan (GOP 2017). Although wheat is a main source of food in Pakistan, comparatively it remains low production efficiency, low productivity leads because of less use of modern technology, and improper wheat inputs (Mirza *et al.* 2015).

Wheat production efficiency affecting by the key factors as wheat land size, seed, pesticides, fertilizers, sowing time, and modern technology (Wagan *et al.* 2015; Abedullah *et al.* 2006; Waqas *et al*. 2014; Nawaz *et al*. 2015; Sattar *et al*. 2015). The land ownership, more use of modern machinery are contributes to wheat productively and efficiency at a high level, while the government policies of marketing management, infrastructure development, contributing directly and indirectly to wheat production efficiency (Passel *et al.* 2006; Akhtar *et al*. 2015). Wheat production increases since green revolution in developing countries.

In Pakistan wheat production efficiency increases since by the introduction green revolution since 1970's. The adoption of modern seed technology improved the wheat productivity remarkably in Pakistan. Since last three decades the production of wheat increased remarkably by the adoption of modern technology and the proper management of input's, to meet countries growing population's food demand (Hussain *et al.* 2012). The

wheat crop productivity was increases from 11.5 million tons to 24 million tons during 1981 to 2009. The production potential increases by time but during 2007 and 2008 Pakistan imported about 8.5 and 15.9% of the wheat to fulfill the domestic wheat demand respectively (Ahmed and Farooq 2010). Figure 1 shows the trend of area and production of grain and wheat crops in Pakistan. The trend of wheat production growth has increases by time but the potential yield per hectare is lower than the potential yield growth (Anonymous, 2011). This yield gap was observed by the different inputs resource use, various soil and climatic conditions and proper availability of irrigation (Hussain *et al.* 2012). The unavailability of proper irrigation system is also the major factor for the gap of wheat production. (Hussain *et al.* 2011).

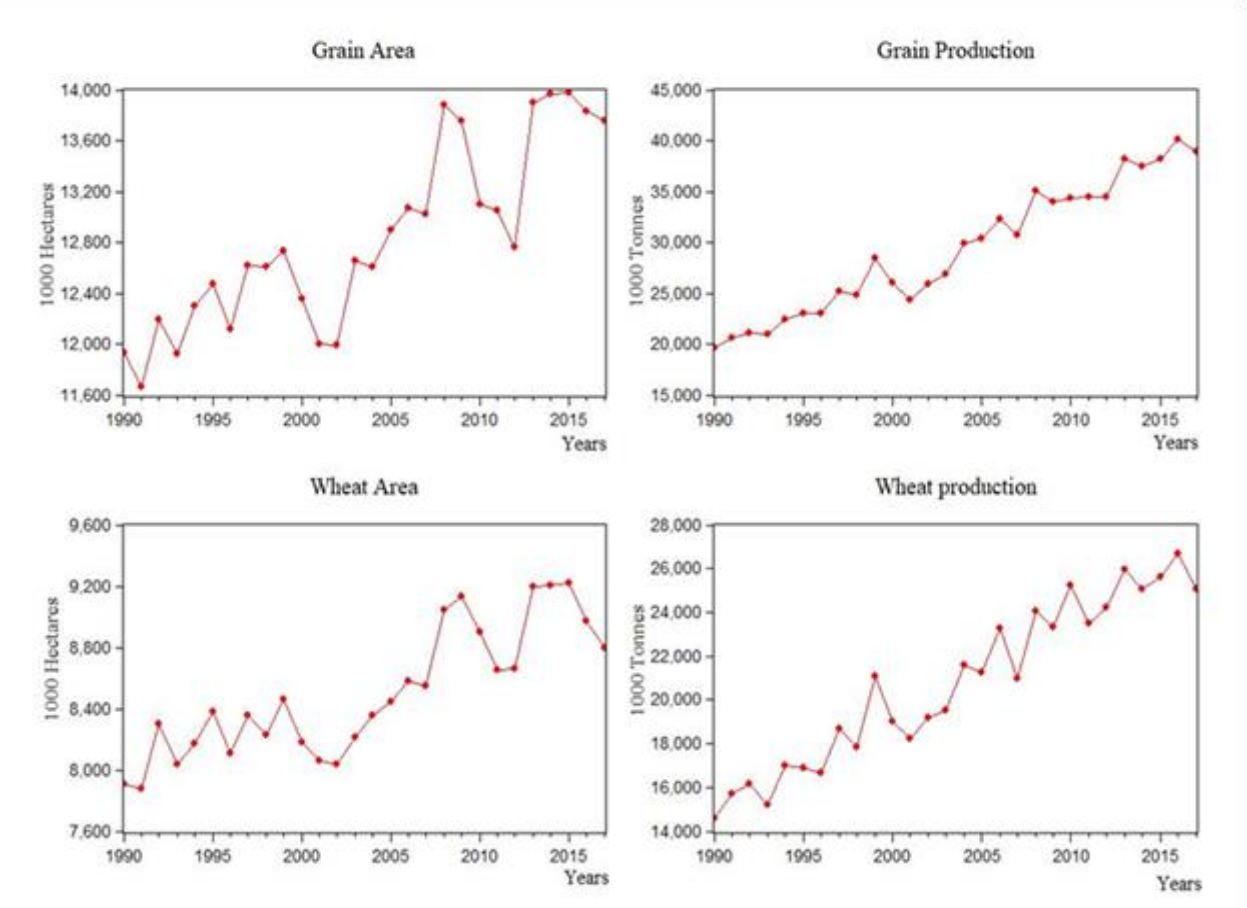

Figure 1: represents the area and production of grain and wheat crops in Pakistan.

Data source: GOP 2018; GOP 2010

China is the world's largest producer and consumer of wheat, it is considered as one of the main staple food and about 60 percent of the China's population consume wheat in different kind of products such as noodles and steamed bums etc. (Zhai *et al*. 2017). In China

the wheat yield increased by the adoption of modern technology and energy use since 1980's and 1990's (Xiang and Huang 2018). The proper input resource use, especially energy inputs and the effective agricultural development policies strengthen the wheat productivity and agricultural growth in China (Shen *et al*. 2018; Li. X, Zhang. Y, Liang. L, 2017).

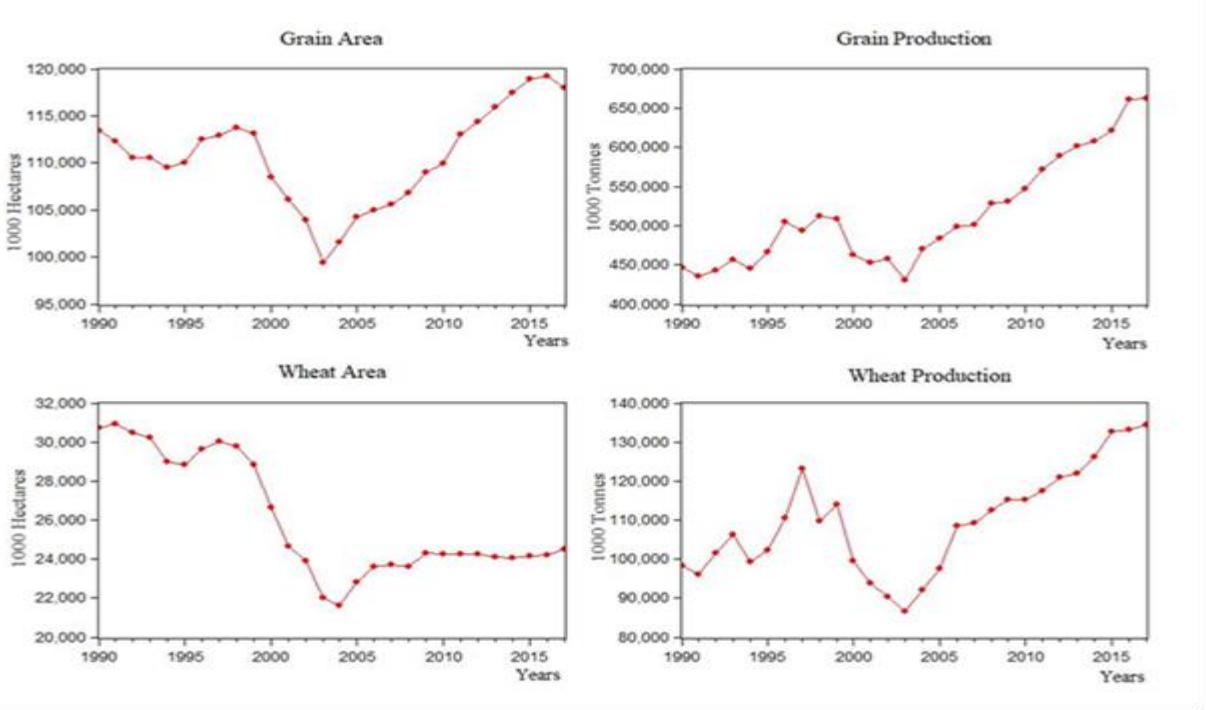

Figure 2 represents the area and production of grain and wheat crops in China

Data source: stats.gov.cn, China Statistical year book various issues.

The figure 2 shows the area and production of grain and wheat crops in China. A scientific literature reported that the modern seed technology of wheat increases 5 percent to 14 percent in total factor productivity during 1982 to 2011 in China (Xiang and Huang 2018). The wheat productivity increased in China by the adoption of modern seed technology, biochemical technology, modern machinery, irrigation technology and input energies (Miao 2014; He *et al*. 2001; Man *et al*. 2015; Pathak and Bining 1985; Shen *et al*. 2018).

Although wheat production increases in Pakistan, there still remains low level of productivity gain while comparing with other developing countries, due to inappropriate application of inputs and non-adoption of modern technology, and the limited availability of irrigation (Abbas *et al.* 2017; Wagan *et al.* 2015, Memon *et al.* 2015). The adoption of modern technology and efficient application input increases the efficiency of agricultural productivity especially wheat productivity (Kizilastan 2008; Wagan *et al.* 2018; Wagan *et al.*

2019). Previous studies explores the various aspects of efficiency analysis in grain food and wheat. Based on our knowledge the research on input resource use and production efficiency of wheat with comparing two developing countries such as China and Pakistan are very scare. Therefore, focus of present study is to understand the wheat production efficiency with combination various production inputs with their proper management. This study contributes to the literature to explore the best combination of input resource usage for the wheat production efficiency and help farmers, researchers and policy maker to understand peak level wheat production efficiency in both countries.

The rest of study is organized as fallows. The consequent section describes the literature about wheat production efficiency, second section briefly describes the methodological frame work, third section explores the results and discussion and the last section shows the conclusion of the study.

2. Literature Review

Ali and Khan (2014) determined the technical efficiency of wheat production in district Peshawar, Khyber Pakhtunkhwa, Pakistan by using stochastic frontier analysis. A sample of 100 wheat farmers were used to estimate the results. The estimated results shows the technical efficiency ranges from 34 to 88%, meanwhile average technical efficiency was 62%. The result shows the wheat production efficiency were increased with efficient usage of inputs such as fertilizer, tractor and labor, however this study explore the wheat farmers education level is also an importer factor for wheat production efficiency.

Buriro *et al*. (2013) analysis the technical efficiency of wheat production in Sindh, Pakistan. The wheat technical efficiency measured by Cobb-Douglas frontier production function, Buriro *et al*. uses primary data of 384 wheat growers from three wheat growing area such as Larkana, Hyderabad and Badin Districts of Sindh province in Pakistan. The results explores the average technical efficiency were 0.36 and it ranges from 0.12 to 0.95. Overall wheat production efficiency were observed better in Hyderabad and Larkana district while wheat production efficiency in Badin were quite low due to limited adoption of modern technology and improper inputs management.

Hussain *et al*. (2016) compared the effect of different sowing methods on wheat productivity and economic feasibility in Pakistan. They chose four sowing methods such as direct drilling method, drilling after the land preparation method, mechanical broadcasting

and the minimum tillage drilling method to examine the economic viability. The economic analysis explores the sowing methods such as drilling after land preparation and the broadcasting are the high cost methods, while the direct drilling and the minimum tillage methods were the lowest cost methods of wheat sowing. The benefit cost ratio were found at optimum level the minimum tillage sowing method, overall study found the wheat crop had maximum yield and more profitable with the proper research management method such as minimum tillage method. Iqbal *et al*. (2018) analyzed the profitability of irrigated and rainfed bread wheat (*Triticum aestivum* L.) crops under foliage applied sorghum and moringa extracts in Pakistan. Through the field trial this study explores the inputs resource such as moringa leaf extract increases the production and benefit cost ratio of wheat crop while sorghum water extract was not effectively increases the wheat productivity.

Huan *et al*. (2019) assess the efficiency and sustainability of wheat production system in different climate in China. The wheat crop is grown in wide range in 15 provinces and three different climatic zones such as subtropical monsoon climate, temperate monsoon climate and temperate continental climate in China. Study explores the different usage of inputs and output different climatic conditions. The results shows the temperate monsoon climate zone and the subtropical monsoon climate zone is the most efficient zone for growing wheat crop in China. Favorable climatic condition and best inputs resource management practice efficiently support the wheat cropping system.

Sureshkumar *et al*. (2014) measured the input resources, cost structure, returns and resource use efficiency in wheat production in India. Study uses primary data of 240 wheat farmers and applied Cobb-Douglas production function to estimate the results. Result explores the agricultural farms with high usage of wheat labor, chemical fertilizer and irrigation charges have highest cost of production and the farmers with more usage of technology and machinery have less cost of production. Study shows the input-output ratio were highest in large wheat farms followed by medium farms and lowest input-output ratio were mentioned in small wheat farms such as 1: 1.48, 1:1.43 and 1:1.35 respectively. Overall study explores the large wheat farms have high wheat production efficiency.

Wang (2010) determined the technical and irrigation water use efficiency in wheat farmers in China. On the basis of primary data of 432 wheat growers' the data envelopment analysis (DEA) were used to determine the technical efficiency of wheat farms and Tobit regression method were used to explore the factors affecting irrigation water during shortage of irrigation water resources. The study results shows the mean technical efficiency by DEA

were 0.6151, however the average irrigation efficiency was 0.3065 which means the wheat farmers can produce with similar quantity of wheat by the usage of same amount of input but benefits about of 69.35 percent less irrigation water. The results of Tobit regression explores the age of wheat growers, income, education level and the farm size has positive impact on water use efficiency, the various irrigation method have significant impact on water usage efficiency. The results further shows the competitive irrigation water price and water property rights were the positive factors for encouragement to water saving behavior.

3. Methodological Framework

3.1. Study area, data collection

Study was conducted in distict Kambar Shahdadkot in Sindh Province in Pakistan, and district Bozhou, Anhui Province in China (Figure 1, 2). Wheat is the major crop in Pakistan which accounts, 9.1 percent in agricultural value added and 1.7 percent in total agricultural GDP of Pakistan, while it and is a second staple food after rice in China and fulfills about 95 percent of food demand with share of rice and corn (GOP 2018; Mai 2008; Kai and Sharon 2018) Anhui and Sindh are very important provinces in terms of wheat production. Anhui is one of important province for wheat production in China, its favorable climatic condition supports to increase the wheat productivity (Zhang *et al.* 2009). The agro-ecological and cropping conditions of both province are similar such as the rice and wheat are the major cereal grain crops of Sindh province, while, in Anhui province the growing major cereal crop are rice, wheat and maize (Mellor and Malik 2016; Tian *et al.* 2019). The similar cropping pattern and significance of wheat productivity, both provinces such as Sindh province and the Anhui province are the good case to compare the wheat input resource usage and production efficiency of wheat. Hence, Sindh province in Pakistan and Anhui Province in China are selected for the study.

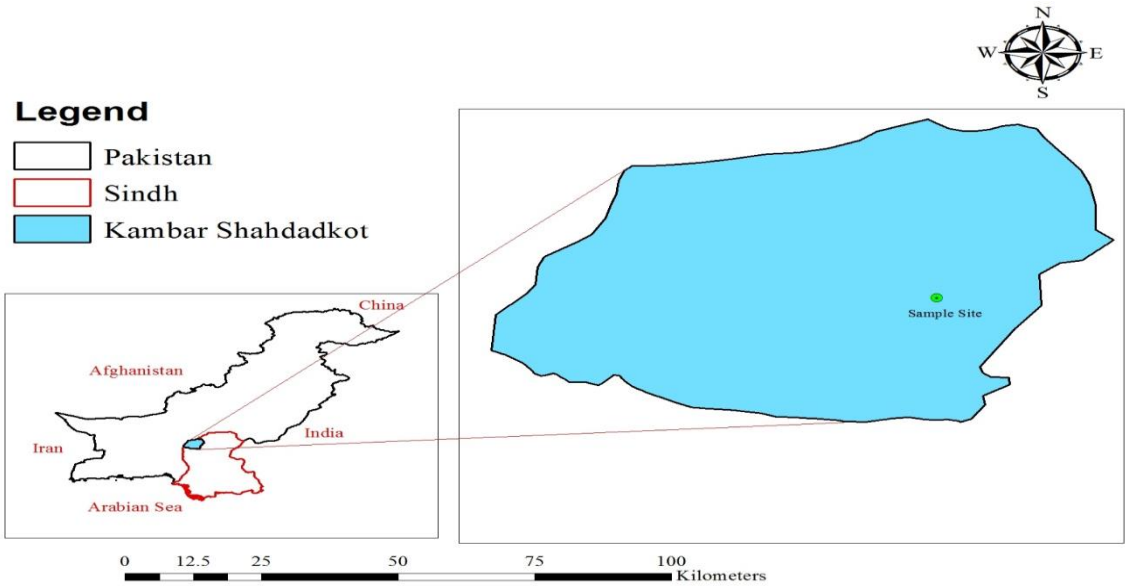

Figure 1: The location of study area, Kambar Shahdadkot, Sindh province of Pakistan.

A primary data collection method with the help of pre-tested questionnaires were used to collect the data. The questionnaire were used to residents of 21 villages in Kambar Shahdadkot and 22 villages in Bozhou during May and June in 2018 with the help of local government. A total of 120 wheat farmers including 60 in Kamaber Shahdadkot and 60 in Bozhou were randomly interviewed. Overall farmers were cooperative and voluntarily participated in survey interviews.

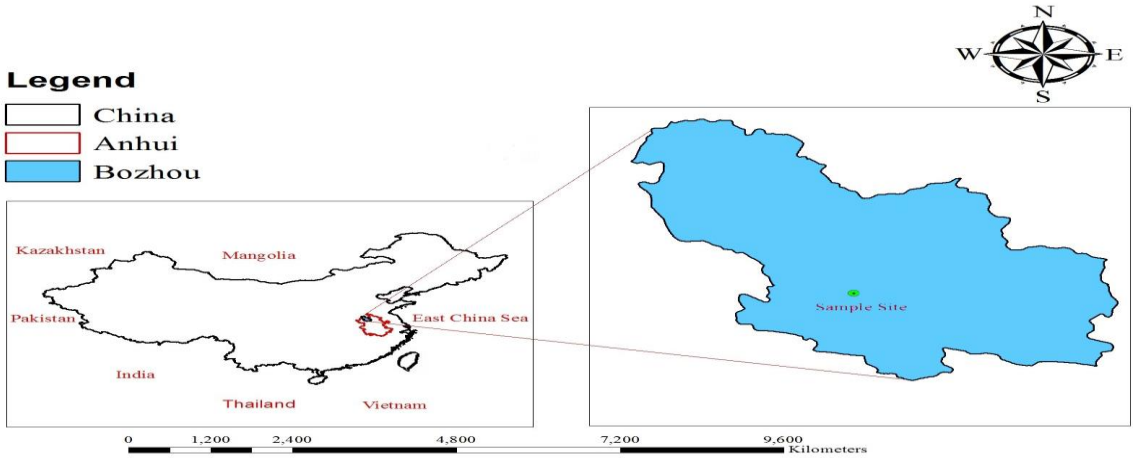

Figure 2: The location study area, Bozhou, Anhui province of China.

3.2. Data analysis

The production efficiency is mostly measures by using Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA), as stated by (Coelli. T. J, Rao. D. S. P, Battese. G. E. 1998). The present study uses Stochastic Frontier Analysis (SFA) to assess the input resource use and production efficiency of wheat in China and Pakistan.

3.3.1 Stochastic frontier analysis

Parametric SFA, which was introduced by (Meeusen and Julien 1977) is a statistical technique for estimating parameters; most empirical studies on the development of the agricultural sector widely use the Cobb–Douglas form of SFA (Battese and Coelli 1995). The current work employed an SFA model to calculate the technical efficiency of rice production in the different agro-ecological zones of Pakistan. The fundamental form of the SFA model can be defined as

$$Y_i = f(x_i;\ \beta)\ \varepsilon_i \qquad (1)$$

Where Yi is the output of the ith wheat farm, xi represents the input variables of the ith wheat farm, β represent the estimated unknown parameters and ε_i the random error term sum of v_i and u_i. While v_i is the ordinary two sided error term assumed to be zero and constant variance, and u_i is the considered as one side error which accounts the shortfall from stochastic frontier.

The empirical model is estimated as:

$$\text{Ln } Y_i = \beta_0 + \beta_1 \ln(\text{land}_i) + \beta_2 \ln(\text{Seed}_i) + \beta_3 \ln(\text{fertilizer}_i) + \beta_4 \ln(\text{pesticides}_i) + \beta_6 \ln(\text{labor}_i) + \beta_7 \ln(\text{Machinery}_i) + v_i - u_i$$

Yi represents the ith wheat farm production; Landi is the land used for the ith wheat farm production; Seedi represents the amount seeds used for the ith wheat farm production; Fertilizeri shows the amount of fertilizer applied in the ith wheat farm production; Pesticidesi relates to the pesticides applied for the ith wheat farm production; Labori stands for labor used for the ith wheat farm production; and Machineryi is the hours of machine used in ith wheat farm. While I represents the number of wheat farm, and ln is the natural logarithm.

For the estimation of technical inefficiency of a household, the non-negative random variable u_i is indicated as follows:

$$|ui| = \delta 0 + \delta 1X1 + \delta 2X2 + \delta 3X3$$

where

X1 = Age of farmer

X2 = Education of farmer

X3 = Farming experience (years)

The empirical SFA model was used to estimates the resource use and wheat production efficiency in between China and Pakistan.

4. Results and Discussion

4.1. Descriptive statics

The descriptive statistics of variables applied in this study are presented in table 1. The variables used for the study are the wheat farm production in mounds, land used for wheat farm in acres, wheat farm used seed in mounds, farm yard manure or green manure or straw used mounds for farm, chemical fertilizer begs used for wheat farm, pesticides used litters in wheat farm, labor persons used for wheat farm and machine used hours for wheat farm, for understanding technical efficiency of wheat farmers the variable used in the study are as farmers age years, education years, and farming experience years. The descriptive statistics shows the mean values of variable is higher than the standard deviation in Pakistan and China. The mean wheat farm production is founded in Pakistan is 228.11 mounds from the mean land size of 4.23 acres, the mean seed value is 9.02 mounds, mean farm yard manure used in wheat is 44.83 mounds, means fertilizer used is 5.84 mounds, mean pesticides used is 1.62 liters for wheat farm, mean labor used is 101.72 persons and the mean value of machinery used for wheat farm is observed as 17.77 hours. The mean age of farmers in Pakistan is found to be 55.08 years, and 6.13 years mean education level is observed and the means farming

experience is founded to be 6.13 years table 1. The results of variable used for wheat farm production efficiency analysis of China is different than the results of Pakistan. The mean production of wheat farms is observed as 309.16 mounds from the mean wheat farm land of 1.18 acres, by using mean seed rate of 1.77 mounds, the mean straw used for wheat farm production is observed as 1317.04 mounds, the mean value of fertilizer mounds, pesticides litters, labor persons and machinery used for wheat farm are founded as 5.84, 2.92, 33.28 and 35.37 respectively. While the mean age, education and farming experience of wheat farmer are found as 55.08, 6.75, and 25.23 years respectively.

Table 1: descriptive statistics of variables used for wheat farm production efficiency analysis

Pakistan					
Variables	**Unit**	**Minimum**	**Maximum**	**Mean**	**Std. Dev.**
Production	Mounds	55.00	728.00	228.11	158.88
Land	Acres	1.00	12.00	4.23	2.40
Seed	Mounds	2.00	24.00	9.02	4.96
Farm Yard Manure/straw	Mounds	10.00	105.00	44.83	23.09
Fertilizers	Begs	0.39	18.45	5.84	4.08
Pesticides	Litters	0.25	7.69	1.62	0.84
Labor	Persons	25.00	302.00	101.72	58.57
Machine	Hours	4.00	45.00	17.77	10.05
Age	Years	19.00	62.00	55.08	11.92
Education	Years	0.00	14.00	6.13	4.62
Farming Experience	Years	1.00	17.00	6.13	4.96
China					
Variables	**Unit**	**Minimum**	**Maximum**	**Mean**	**Std. Dev.**
Production	Mounds	29.75	825.00	309.61	220.55
Land	Acres	0.13	3.29	1.18	0.73
Seed	Mounds	0.20	6.59	1.77	1.28
Farm Yard Manure/Straw	Mounds	166.03	3706.76	1317.04	705.46
Fertilizers	Begs	0.40	18.45	5.84	4.08
Pesticides	Litters	0.42	7.69	2.92	1.74
Labor	Persons	12.14	169.96	33.28	32.59
Machine	Hours	1.20	111.73	35.37	25.25
Age	Years	26.00	88.00	55.08	15.29
Education	Years	0.00	14.00	6.75	4.33
Farming Experience	Years	5.00	45.00	25.23	10.34

Source: Authors calculations by using Eviews 8 version

4.2. Maximum Likelihood Estimates (MLE)

The result of maximum likelihood shows that the parameters like land size, farm yard manure, and pesticide application are positively and significantly affect to wheat farm production in Pakistan, and farmers age and farming experience have positive and significant effect, while machines use have no significant effect on wheat production in Pakistan.

However, in China the land size acres, wheat seed and machine usage hours are positively and significantly affected to wheat production in China, similarly faring experience have positive and fertilizer usage, labor and farmers age have negative and significant effect to wheat production. This results also supported by the studies of (Hussain *et al.* 2012, Mirza *et al.* 2015; Miao 2014; Wang *et al*. 2018; Memon *et al.* 2015). The results established that in both countries, the farmers' more availability of quality land more faming experience positively affected wheat production. While results of China shows there in more use of machinery in wheat production which favorably affected to wheat production compared to Pakistan (Table 2).

Table 2: Maximum Likelihood Estimates (MLE) results of stochastic frontier analysis

	Pakistan			**China**		
Variables	**Coefficient**	**Std-error**	**t-ratio**	**Coefficient**	**Std-error**	**t-ratio**
Intercept (β_0)	-0.75*	0.41	-0.18	0.14***	0.11	0.13
Land (β_1)	0.11***	0.24	0.24	0.14***	0.10	0.14
Seed (β_2)	0.17	0.24	0.73	0.25**	0.10	0.24
Farm Yard Manure/Straw (β_3)	0.79**	0.14	0.56	0.36	0.36	0.99
Fertilizer (β_4)	0.27	0.78	0.34	-0.98*	0.21	-0.47
Pesticides (β_5)	0.64*	0.32	0.20	0.28	0.23	0.12
Labor (β_6)	-0.79*	0.64	-0.12	-0.73**	0.22	-0.33
Machine used hours (β_7)	0.21	0.62	0.34	0.25***	0.85	0.30
Technical inefficiency						
Age of farmer (β_8)	0.18*	0.16	0.11	-0.36*	0.82	-0.43
Education years (β_9)	-0.20	0.15	-0.14	-0.80	0.88	0.90
Farming experience (β_{10})	0.11*	0.12	0.91	0.53***	0.20	0.27
sigma-squared (σ^2)	0.23***	0.10	0.23	0.24***	0.10	0.24
gamma (γ)	0.99***	0.12	0.84	0.99***	0.26	0.37
log likelihood function	-0.28					
log likelihood function	-0.34					
LR test of the one-sided error	0.19					
LR test of the one-sided error	0.29					

Note * P<0.1percent, **P<0.05 percent and ***P<0.01 percent significant level.

4.3. The technical efficiency of wheat farms in Pakistan and China.

The results of technical efficiency presented in table 03. The range of estimated technical efficiency of wheat farms in Pakistan and China is observed from 0.41 to 0.99, shows the capability of wheat farms to produce efficient wheat production. The mean technical efficiency of both countries are 0.80 percent and 0.82 percent in Pakistan and China respectively which shows 80 percent of wheat farms are technical efficient in wheat production in Pakistan and 82 percent of wheat farm in China are capable to produce efficient to production. Study further states that about 3.33 percent of wheat farms in Pakistan have lowest production efficiency 0.41 to 0.50, and the about 26.67 percent wheat farms in are getting efficient wheat production ranged 0.91 to 0.99. While results of China represented that about 5.01 percent of wheat farms are lowest efficient in wheat production ranged as 0.41 to 0.50, and comparatively more farms as 33.33 percent have efficient wheat production, as the efficiency ranged from 0.91 to 0.99. Overall, technical efficiency results of wheat farms in China is greater than then the Pakistan because of more use of modern technology and machinery (Table 3). Similar results observed as the modern technology, and more used of machinery, and energy, proper irrigation management are major component of wheat production efficiency (Shen *et al*. 2018; Lv *et al.* 2017, Wagan *et al.* 2015, Memon *et al.* 2015, Ghorbani *et al*. 2011).

Table 3: The technical efficiency results of Pakistan and China

Pakistan			**China**	
Technical Efficiency Level	**Wheat Farms**	**Percentage**	**Wheat Farms**	**Percentage**
0.31 to 0.40	0	0.00	0	0.00
0.41 to 0.50	2	3.33	3	5.01
0.51 to 0.60	9	15.00	6	10.00
0.61 to 0.70	10	16.67	8	13.33
0.71 to 0.80	11	18.33	11	18.33
0.81 to 0.90	12	20.00	12	20.00
0.91 to 0.99	16	26.67	20	33.33
Total	60	100.00	60	100.00
Mean technical efficiency	0.80	0.83		

Source: Authors calculations by using Frontier 4.1 program

5. Conclusion

The study estimates the production efficiency of wheat farms in Pakistan and China, understand the productivity and technological different in wheat farms in both countries. The results estimated by the application of stochastic frontiers analysis, the econometric results of Maximum likelihood estimates (MLE) shows the wheat farm size, and farming experience of wheat farmers in both countries are the major favorable component of wheat production in both countries. However, the wheat seed and more use of machinery in wheat farms are positive point of China's wheat production over wheat farm production of Pakistan. The results sows the 26.67 of wheat farm have highest wheat production efficiency in Pakistan, However, in China more farms about 33.33 percent of wheat farms have highest farm production efficiency. The wheat farms in China have applied more machinery use and modern seed for highest wheat productivity. Therefore study concluded that China have highest wheat farm production efficiency comparing to Pakistan, due to adoption of modern seed technology and more usage of machinery and proper usage of input resources. The study finding may helpful for researchers, policy makers, and farmers of both countries to understand the components of wheat production efficiency.

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