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Assessing the Efficiency of Apple Growers in Himachal Pradesh Using DEA approach

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Abstract
The present study assesses the efficiency of apple growers in Himachal Pradesh using DEA, shedding light on factors influencing performance and suggesting strategies to optimize resource allocation and enhance yield. Apple growers have made various efforts to improve their performance as their efficiency levels vary. The cross-sectional data collected aims to evaluate the technical efficiency of 120 apple growers in Himachal Pradesh. Results show that the study found that 59.2% of apple growers in the region are efficient, while 40.8% need to improve their efficiency. Larger farmers tend to have higher average farm income, and smaller farmers have lower average income. The Tobit regression results show that factors such as educational level, farm size, farmer's age, and assets owned have an inverse relationship with efficiency. This means that as these factors decrease, the efficiency of the growers increases. On the other hand, variables such as farm experience, occupation, family size, and distance from home to farm are directly related to efficiency, indicating that the technical efficiency of the apple growers increases with greater farm experience, occupation, household size, and distance.

Keywords*: Data Envelopment Analysis, Determinants, Himachal Pradesh, Technical Efficiency, Apple Growers.*

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I. Introduction

In the realm of agriculture economics, various studies have emphasized the importance of efficiency analysis to gauge the performance of agriculture sector in general. Some empirical studies offer estimates of Technical Efficiency for apple crop production within a specific state or region. The technical efficiency of apple farmers in various regions has been measured by different researchers. For example, Gul (2006) conducted a study in Isparta, Karaman, and Nigde provinces of Turkey. Lijia, Huo, and Kabir (2013) focused on the Shaanxi region of China. Minhas (2014) studied apple growers in Kullu District of Himachal Pradesh. Murtaza (2017) researched apple growers in the Balochistan Plateau of Pakistan**.** Studies like Bhatt & Bhat (2014), in their study estimates the technical efficiency of 461 farmers from district Pulwama of Jammu & Kashmir for the year 2013-14 by employing Non-parametric Data Envelopment Analysis. Their study observed that most of the farms were operating at a low level of technical efficiency. Only 48 per cent farmers were found to be technically efficient which means that 52 percent farmers are technically inefficient. Farm experience, occupation, Farm size, Household size, Membership, and Seed type were assumed to be the main determinants of their inefficiency. On the other hand, Gul (2006), estimated technical efficiencies of apple production of 129 agricultural enterprises in Turkey during 2001 by employing Data Envelopment Analysis experienced that the mean efficiency of sample apple farms was estimated to be 0.60 for constant return to scale assumption and 0.90 for variable returns to scale assumption. Total farm size is likely to be the most significant factor affecting efficiency. While Shanmugam & Venkataramani (2006), in their study, talked about district-level cross-sectional secondary data of agricultural output for the year 1990-91 by employing the Stochastic frontier production function model. They observed that the average technical efficiency is found to be 79.32 percent in India which means 20.68 percent of farmers need to increase their agricultural output through existing inputs and technology. Health, Education, and Infrastructure were supposed to be the main sources of efficiency. The findings from these studies can provide valuable insights for policymakers in formulating development policies for the apple crop. Nonetheless, little effort has been made to evaluate the Himachal Pradesh apple growers' technological efficacy. In the present study the technical efficiency of Himachal Pradesh apple growers is

estimated to study their performance. The study also makes an effort to pinpoint the several elements influencing Himachal Pradesh's levels of technical efficiency

Objectives of the study

To evaluates the efficiency of apple farming practices in Himachal Pradesh and identify the key factors contributing to efficiency and offering recommendations for agricultural development

II. Research Methods and Methodology

The present study is based on primary data gathered through a well-structured interview schedule. The main purpose of this section is to formulate a methodology comprising of the following.

A. Selection of the Area

The universe for conducting the present study is Shimla, Kullu, and Kinnaur districts from Himachal Pradesh are selected purposively for field study. The reason behind this is that these districts cover the highest area and production of apple cultivation. Therefore, finally, three districts are considered for study from Himachal Pradesh.

Selection of sample Apple Growers

Shimla: In Shimla district there are 12 tehsils viz. Rampur, Kumarsain, Sunni, Shimla(R), Shmila(U), Thog, Chaupal, Jubbal, Kotkhai, Rohru, Chirgaon and Dodra Kawar. Among them Rohru and Jubbal are highest apple producing valleys and majority of apple growers are found in these tehsils. Therefore, 20 apple growers from Rohru and 20 from Jubbal tehsils are selected for the study purpose.

Kullu: In Kullu, there are five tehsils viz. Kullu, Nirmand, Banjar, Manali and Anni. Among them Kullu and Manali are selected for the study.

Kinnaur: Kinnaur district has six tehsils. Among them Sangla and Poo are major apple producing tehsils and majority of apple growers are found in these tehsils. Therefore 20 apple growers from Sangla and 20 from Poo tehsils are selected purposively for collecting the primary data.

B. Methodology

Technical Efficiency is computed by Data Envelopment Approach (DEA). Technical Efficiency under Constant returns to scale as given by Charnes, Cooper and Rhodes propounded a model in 1978 which is input oriented and assumed constant returns to scale. While Technical Efficiency Under Variable Returns to Scale is estimated as given by Banker, Charnes and Cooper (1984). BCC suggested an extension version of Constant Returns to Scale Data Envelopment Analysis model to account for Variable Returns to Scale situation. The use of Variable Returns to Scale specifications will permit the calculations of Technical Efficiency devoid of scale efficiencies effect. DEA software which is freely given is used to estimate TE and its different forms.

Estimation of Tobit Regression

Tobit regression model is used to calculate the determinants of inefficiencies of apple growers of Himachal Pradesh. It is estimated as follows:

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + Ui}$$

Where,

Y is the dependant variable (Technical Efficiency Score ranges between 0 to 1). The proposed determinants of technical efficiency include: X_1= Education (years of schooling); X_2=Farm size (Kanals); X_3= Farm Experience (years); X_4= Occupation (1= if agriculture and 0 = Non-agriculture); X_5= Age of the farmer (years); X_6= Household size (number of family members); X_7= Owned Assets (in rupees); X_8= Distance to farmland (kms); U_i is the error term.

III. Results and Explanations

Descriptive Statistics of sample apple growers in Himachal Pradesh

The table below shows the descriptive statistics of sample apple growers in Himachal Pradesh. It illustrates variations in the inputs used for apple production across different farm sizes (Small, Medium, Large). The input for labour is expressed as hired labour per year. The area under apple cultivation is expressed as the total area in Kanals. Fertilizer usage is expressed in kilograms per Kanal, and pesticides are expressed in liters per Kanal.

Table 1
Descriptive Statistics of sample apple growers in Himachal Pradesh

Variable	Unit	Small (N=31)			Medium (N=60)			Large (N=29)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Farm Income	Rs/Kanal	49000	130000	92000	55000	162000	104783	55000	188000	112621
Area under Cultivation	Kanal	3	15	9.35	10	35	19.17	35	80	50.76
No. of Labour days	Per Kanal	88	290	184.35	85	300	183.75	89	310	194.76
Fertilizer	Kg/Kanal	285	1425	888.71	950	2850	1816.08	3325	7600	4822.07
Pesticides	Litre /Kanal	6	32	19.65	21	63	40.15	74	168	106.59

***Source*:** Field Survey (2018).

The average farm income of small, medium, and large farmers is Rs 92000, Rs 104783, and Rs 112621 per Kanal, respectively. In general, the average farm income increases with the farm size. The average area under apple cultivation for small, medium, and large farmers is 9.35 Kanals, 19.12 Kanals, and 50.76 Kanals, respectively. Large farmers tend to use more labour compared to medium and small farmers, and they also use a higher quantity of fertilizer and pesticides.

Furthermore, the frequency distribution in Table 2 of the Tobit Regression Model in Himachal Pradesh reveals that small farmers are generally more educated than medium and large farmers. The distribution of farm experience shows that 51.61% of small growers, 33.33% of medium growers, and only 13.79% of large apple growers have up to 10 years of farm experience. Additionally, 32.26% of small growers, 25% of medium growers, and 51.72% of large apple growers have 11 to 20 years of farm experience, while 16.13% of small growers, 41.67% of medium growers, and 34.48% of large apple growers have more than 21 years of experience in Himachal Pradesh.

Table 2
Descriptive Statistics of the Variables used in Tobit Regression Model for Himachal Pradesh

Variables	Unit	Small		Medium		Large	
		Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Education in Years	Illiterate	2	6.45	8	13.33	5	17.24
	Up to 8th	17	54.84	18	30.00	5	17.24
	9th to 12th	4	12.90	25	41.67	6	20.69
	Above 12th	8	25.81	9	15.00	13	44.83
Total		**31**	**100.00**	**60**	**100.00**	**29**	**100.00**
Farm Experience in Years	Up to 10 years	16	51.61	20	33.33	4	13.79
	11-20 years	10	32.26	15	25.00	15	51.72
	21 Y and above	5	16.13	25	41.67	10	34.48
Total		**31**	**100.00**	**60**	**100.00**	**29**	**100.00**

Occupation	Agriculture	18	58.06	40	66.67	20	68.97
	Non-Agriculture	13	41.94	20	33.33	9	31.03
Total		**31**	**100.00**	**60**	**100.00**	**29**	**100.00**
Age in Years	Up to 50 Y	15	48.39	42	70.00	22	75.86
	Above 50 Y	16	51.61	18	30.00	7	24.14
Total		**31**	**100.00**	**60**	**100.00**	**29**	**100.00**
Family Size in Numbers	Up to 10	19	61.29	47	78.33	14	48.28
	Above 10	12	38.71	13	21.67	15	51.72
Total		**31**	**100**	**60**	**100**	**29**	**100**
Family Assets in Lacs	Up to 5 Lac	20	64.52	32	53.33	12	41.38
	Above 5 Lac	11	35.48	28	46.67	17	58.62
Total		**31**	**100**	**60**	**100**	**29**	**100**
Distance in Km	Up to 1 km	20	64.52	22	36.67	9	31.03
	Above 1 km	11	35.48	38	63.33	20	68.97
Total		**31**	**100**	**60**	**100**	**29**	**100**

***Source*:** Field Survey (2018).

In the surveyed population, 58.06% of small growers, 66.67% of medium growers, and 68.97% of large growers listed agriculture as their main occupation. Additionally, 41.94% of small growers, 33.33% of medium growers, and 31.03% of large apple growers reported agriculture as their subsidiary occupation. With regards to age distribution, 48.39% of small growers, 70% of medium growers, and 75.86% of large growers are under 50 years old, while 51.61% of small growers, 30% of medium growers, and 24.14% of large growers are over 50 years old. In terms of family size, 61.29% of small growers, 78.33% of medium growers, and 48.28% of large growers has up to 10 family members, while 38.71% of small growers, 21.67% of medium growers, and 51.72% of large growers has more than 10 family members. As for family assets, 64.52% of small farmers, 53.33% of medium farmers, and 41.38% of large farmers has family assets up to Rs 500000, while 35.48% of small growers, 46.67% of medium growers, and 58.62% of large growers has family assets exceeding Rs 500000.

Efficiency Estimates through Data Envelopment Analysis (DEA) in Himachal Pradesh

To identify the causes of inefficiency, in the present study, technical efficiency (CRS), pure technical efficiency (VRS), and scale efficiency is estimated using DEA approach. If a farmer's technical efficiency score falls between 0.90 and 1, they are considered efficient. The results indicate that scale efficiency, rather than technical efficiency, is the primary source of overall inefficiency.

Technical Efficiency (CRS) of sample apple growers in Himachal Pradesh

In Himachal Pradesh, the average technical efficiency is 0.592. This means that, on average, the respondents are able to achieve about 59.2% of potential outputs from a given mix of inputs. It also indicates that around 40.8% is lost due to technical inefficiency. In other words, an average of 40.8% of output is not achieved due to the inefficient use of factors that were within the control of growers. The technical efficiency level of apple growers ranged from 0.169 to 1.

Table 3
Percentage Distribution of the sample apple growers by Technical Efficiency Estimates (CRS) in Himachal Pradesh

	Small		Medium		Large		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
<0.50	8	25.81	12	20	14	48.28	46	38.33
0.50<0.90	16	51.61	39	65	9	31.03	60	50
0.90<1	7	22.58	9	15	6	20.69	14	11.67
Total	31	100	60	100	29	100	120	100
Minimum	0.361		0.359		0.270		0.169	
Maximum	1		1		1		1	
Mean	0.673		0.673		0.605		0.592	

***Source*:** Field Survey (2018).

The levels vary across different farm sizes. For small, medium, and large farms, the range of technical efficiency is 0.361 to 1, 0.359 to 1, and 0.270 to 1, respectively. The average technical efficiency is the same for small and medium-sized growers at 0.673, which is higher than the efficiency of large growers at 0.605. Specifically, 22.58% of small farmers, 15% of medium farmers, and 20.69% of large farmers were technically efficient. The percentage of technically efficient farmers decreases to 15% for medium farmers and 20.69% for large farmers. Overall, 11.67% of farmers were technically efficient in Himachal Pradesh, as shown in Table 3.

Pure Technical Efficiency (VRS) of sample apple growers in Himachal Pradesh

In table 4, the pure technical efficiency accounting for variable returns to scale (VRS) is shown. The mean technical efficiency scores for small, medium, and large growers are 0.786, 0.774, and 0.851, respectively. The technical efficiency under variable returns to scale for small, medium, and large apple growers ranges between 0.505 to 1, 0.484 to 1, and 0.639 to 1, respectively. The overall technical efficiency under variable returns to scale varies between 0.274 to 1. The estimated results indicate that the overall mean technical efficiency under variable returns to scale is 0.716 (71.6 percent), which means apple growers in Himachal Pradesh were not operating at optimal scale.

Table 4
Percentage Distribution of the sample apple growers by Pure Technical Efficiency Estimates (VRS) in Himachal Pradesh

	Small		Medium		Large		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
<0.50	0	0	4	6.67	0	0	20	16.67
0.50<0.90	19	61.29	35	58.33	19	65.52	67	55.83
0.90<1	12	38.71	21	35	10	34.48	33	27.5
Total	31	100	60	100	29	100	120	100
Minimum	0.505		0.484		0.639		0.274	
Maximum	1		1		1		1	
Mean	0.786		0.774		0.851		0.716	

***Source*:** Field Survey (2018).

The analysis reveals that there is approximately 28.4% potential to reduce input costs or increase output with the same input level. The results indicate that 38.71% of small growers, 35% of medium growers, and 34.48% of large farmers in Himachal Pradesh were technically efficient under variable returns to scale.

Additionally, the overall findings demonstrate that 27.5% of apple growers in Himachal Pradesh were technically proficient during the study period.

Scale Efficiency of sample apple growers in Himachal Pradesh

In Table 5 the average scale efficiency for small, medium, and large apple growers is shown to be 85%, 87%, and 69.5% respectively. This implies that small and medium apple growers in Himachal Pradesh had higher scale efficiency compared to technical efficiency under variable returns to scale, while large growers had lower scale efficiency compared to technical efficiency. At the aggregate level, the mean scale efficiency was calculated as 82.8%, which was also relatively higher compared to technical efficiency under variable returns to scale in Himachal Pradesh. The table indicates that overall scale efficiency scores ranged between 0.442 to 1. For small apple growers, scale efficiency varied between 0.529 to 1, for medium apple growers it varied between 0.455 to 1, and for large apple growers, it ranged between 0.320 to 1. This suggests that, on average, the scale inefficiencies of apple growers in the study area were around 17.3%. The percentage of scale-efficient farmers varied across different farm sizes, decreasing from 51.61% for small growers to 48.33% for medium growers and 24.14% for large apple growers.

Table 5
Percentage Distribution of the sample apple growers by Scale Efficiency Estimates in Himachal Pradesh

	Small		Medium		Large		Total	
	Frequency	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
<0.50	0	0	1	1.67	5	17.24	3	2.50
0.50<0.90	15	48.39	30	50	17	58.62	65	54.17
0.90<1	16	51.61	29	48.33	7	24.14	52	43.33
Total	31	100	60	100	29	100	120	100
Minimum	0.529		0.455		0.32		0.442	
Maximum	1		1		1		1	
Mean	0.85		0.87		0.695		0.828	

***Source*:** Field Survey (2018).

Comparison of sample Apple Growers with various return to scale in Himachal Pradesh

Table 6 indicates that 5 percent of apple growers in Himachal Pradesh achieve a scale efficiency score of 1, which means they are operating at the Most Productive Scale Size (MPSS) with constant returns to scale. During the study period, 69.17 percent of apple growers were operating with increasing returns to scale, while 25.83 percent were operating under decreasing returns to scale. This suggests that most apple growers were in the early expansionary stage, indicating potential for improving efficiency through proper reallocation of resources. Only 5 percent of the total number of growers were found to be operating efficiently under both Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) at the Most Productive Scale Size (MPSS)

Table 6
Comparison of the number and percentage of sample Apple Growers with various return to scale in Himachal Pradesh

Category	**Small**		**Medium**		**Large**		**Total**	
Scale Efficient Farmers	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Constant	3	9.68	5	8.33	4	13.79	6	5
Decreasing	2	6.45	14	23.33	1	3.45	31	25.83
Increasing	26	83.87	41	68.33	24	82.76	83	69.17
Total	**31**	**100**	**60**	**100**	**29**	**100**	**120**	**100**

***Source*:** Field Survey (2018).

In the study, it is found that 31 apple growers (25.83%) are operating under Decreasing Returns to Scale (DRS) while 83 apple growers (69.17%) are operating under Increasing Returns to Scale (IRS). The data in Table 6 also reveals that a high percentage of scale-efficient growers were in the group of large apple growers (13.79%). More than 13% of apple growers were operating at Most Productive Scale Size (MPSS), while only 9.68% of small farmers were operating at MPSS. The majority of apple growers operated below the optimal scale, with 83.87% of small apple growers, 68.33% of medium apple growers, and 82.76% of large apple growers operating under Increasing Returns to Scale (IRS), indicating that their productivity could be increased further. The data also indicated that about 6.45% of small apple growers, 23.33% of medium apple growers, and 3.45% of large apple growers are operating under decreasing Returns to Scale (DRS), implying that their productivity could be increased by a smaller proportion.

Tobit Regression Model Results of sample apple growers of Himachal Pradesh

In this section, the determinants of inefficiency is estimated using the Tobit Regression Model. Table 7 displays the estimated results of the Tobit Regression. The model is deemed appropriate since the p-value is 0.0374747 and is significant at the 1% level. Additionally, the Mean of the Dependent Variable (TE) is 0.7158, and the Standard Deviation of the Dependent Variable is 0.208346, with a log-likelihood of 42.1963.

The findings indicate that the education of the farmers has a negative relationship with farm efficiency, although it is not statistically significant. Specifically, the results show that an increase of one year in schooling is associated with a 1.7% decrease in farm efficiency, suggesting that education does not contribute to improved efficiency among farmers. Similar results were reported by Rajendren (2014) and Liu et al. (2019). Farm size is found to harm technical efficiency, which was statistically significant at the 10% level. This implies that a one kanal increase in farm size results in a 0.3% decrease in grower efficiency. On the other hand, farm experience has a positive influence on the technical efficiency of the sampled apple growers and is significant at the 10 % level. The results indicate that a one-year increase in farm experience leads to a 1.3 % rise in the technical efficiency of apple growers in Himachal Pradesh. Similar results are also reported by Bhatt & Bhat (2014).

Table 7
Tobit Regression Results of sample apple growers in Himachal Pradesh

VARIABLE	COEFFICIENT	STD.ERROR	T- STAT	P-VALUE
Constant	0.825915	0.104515	7.902	<0.00001
Education	-0.017134	0.011195	-1.531	0.12589
Farm Size	-0.003453	0.001511	-2.285	0.02233 **
Farm exp.	0.013705	0.005727	2.393	0.01672**
Occupation	0.145895	0.067106	2.174	0.02970**
Age	-0.009091	0.004677	-1.944	0.05194 *
Household Size	0.007714	0.018281	0.422	0.67304
Owned Assets	-0.033167	0.069124	-0.480	0.63136
Distance	0.032726	0.049702	0.658	0.51025
Mean of Dependent Variable = 0.7158 Standard Deviation of Dependent Variable. = 0.208346		Sigma = 0.170235 Log-likelihood = 42.1963 Test statistic: Chi-square (2) = 6.56818 with p-value = 0.0374747		

***Source*:** Field Survey (2018).

Note: *Significant at 5% Level, **Significant at 10% Level.

In Himachal Pradesh, the primary occupation of apple growers has a positive effect on technical efficiency, which is significant at the 10 percent level. The results suggest that as the occupational pattern shifts from agriculture being the main occupation to agriculture being a secondary occupation, the probability of technical efficiency increases by 14.58 percent.

The age of the household head has a negative effect on technical efficiency and is significant at the 5 percent level. The findings indicate that an increase in the age of the farmer by one year reduces the probability of technical efficiency by 0.9 percent. This implies that younger apple growers in Himachal Pradesh are more technically efficient than their older counterparts, which is consistent with similar results reported by Rajendran (2014) and Tipi (2009). Household size is an important variable, especially in labor-intensive Indian agriculture. The results of this study show a positive but insignificant relationship between household size and technical efficiency. This means that an increase in the number of family members increases the probability of technical efficiency for farmers. However, due to the insignificant relationship, apple growers did not benefit from

increasing the number of family members, similar to the situation in Jammu & Kashmir. Household assets show a negative and insignificant relationship at the 1 percent level. The results indicate that household assets lead to a decrease in the probability of technical efficiency of apple growers in Himachal Pradesh by 3.3 percent. The distance between apple growers' home and farmland shows a negative relation with the technical efficiency of farm productivity, but the relationship is not significant. The results suggest that an increase in the distance to the farmland by one kilometre led to a 3.2 percent decrease in technical efficiency. Thus the results shows that more the distance leads to more cost (Bhatt & Bhat, 2014).

IV. Conclusion

The study used Data Envelopment Analysis to assess the technical efficiencies of apple growers in Himachal Pradesh. The findings indicated that 59.2% of apple growers in the region are efficient. The mean technical efficiency for pure technical efficiency (VRS) is 71.6%, and 82.8% of apple growers demonstrated scale efficiency. Additionally, 69.17% of apple growers shows increasing returns to scale, 25.83% had decreasing returns to scale, and 5% demonstrated constant returns to scale. The average farm income for small, medium, and large farmers is Rs 92000, Rs 104783, and Rs 112621 per Kanal, respectively. Larger farm means higher incomes. The average area under apple cultivation for small, medium, and large farmers is 9.35, 19.12, and 50.76 Kanals, respectively. Large farmers use more labour, fertilizer, and pesticides. Small farmers are generally more educated, and a higher percentage of small growers have more than 21 years of experience. The Tobit regression results reveal that in Himachal Pradesh, factors such as educational level, farm size, farmer's age, and assets owned displayed an inverse relationship with efficiency. This means that as these factors decrease, the efficiency of the growers increases. On the other hand, variables such as farm experience, occupation, family size, and distance from home to farm exhibited a direct relation with efficiency, indicating that the technical efficiency of the apple growers increases with greater farm experience, occupation, household size, and distance. In Himachal Pradesh, the main occupation of apple growers significantly affects technical efficiency, with a shift from primary to secondary agriculture increasing the probability of technical efficiency. Farmers of lesser age groups are more efficient than the higher age groups. Household size has an insignificant impact on efficiency, while household assets and distance to farmland negatively affect technical efficiency.

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