Substitution And Complementarity Between Energy Inputs In Cotton Cultivation In Tamil Nadu

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INTRODUCTION

India occupies an important place among the cotton-growing countries of the world. Cotton plays a dominant role in India's agrarian and industrial economy. India is the world's third largest producer of cotton, after China and United States of America. Cotton production has been the special pride of India for many centuries. Cotton, the most extensively grown cash crop has been known in Tamil Nadu since 1790, when the Bourbon cottonseed obtained from Malta and Mauritius were first distributed among the cultivators. Energy is a primary input in the agricultural process. The energy utilization is the indicator of the level of economic development. Prior to the introduction of green revolution in the mid-sixties, energy requirements of Indian agriculture were largely met from traditional and renewable sources such as human labour, bullock labour and manure. At present, more than fifty per cent of the energy used in agriculture comes from non-renewable sources. The technological change has led to an increase in demand for commercial energy-based modern inputs namely mechanization, chemical fertilizers and the like. It has been observed by S. Singh and J. P. Mittal that the use of modern inputs is biased towards irrigated crops, mainly because of a higher degree of complementarity of modern inputs with irrigation. Hence, the present study attempts to examine the substitutability and complementarity between renewable and non-renewable energy inputs used in the production of cotton, particularly two popular varieties namely MCU-5 and LRA-5166 varieties in Tamil Nadu.

OBJECTIVES

The main objective of the present study is to analyze and compare the MCU-5 and LRA-5166 varieties of cotton cultivation. The specific objectives are:

1) To analyze the substitution and complementarity aspect of different energy inputs for small and large farmers and;

2) To estimate own and cross price elasticities of demand of different energy inputs for small and large farmers.

METHODOLOGY

Cotton as a cash crop plays a considerable role in the crop economy of Tamil Nadu. Virudhunagar district is one of the most important districts in Tamil Nadu which has witnessed significant agricultural development, particularly in the area of cotton cultivation. Among the 32 districts in Tamil Nadu, Virudhunagar district stands first in the area under cotton cultivation. This is the reason that there are about 76 cotton mills situated in this district. Virudhunagar district comprises of 11 Blocks. Among the eleven blocks, the Sattur block and Aruppukkottai block, which have the largest area under cotton had been selected as the study area for the collection of primary data. Both Sattur and Aruppukkottai block consist of 148 revenue villages. These villages were arranged in a descending order of area under sugarcane, and the first 10 villages were selected, which amounted for more than 70 per cent of the cotton cultivation in these blocks. The proportionate random sampling technique had been adopted based on the area under cultivation of cotton in each block to select 100 sample farmers each, in MCU-5 and LRA-5166 cotton varieties for primary data collection. Personal interview method was employed to collect information from the cotton cultivators. Normally, in Virudhunagar district, rains are received during October or November. The survey was conducted during the months between October 2009 and March 2010 of the agricultural year 2009-10. The physical unit into energy units has been converted based on the methods of Prakash Metha and Rocco et. al.

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THE ANALYTICAL FRAMEWORK

Substitutability or Complementarity of energy inputs can be measured from the estimation of Allen Elasticity of Substitution (AES) derived from translog cost function. The following form of translog cost function has been used for the present study.

$$
\begin{aligned}
\log C = \; & \alpha_0 + \sum_{j=1}^{5} \alpha_i \log P_i + \alpha_6 \log Y + ½\, \beta_{11}(\log P_1)^2 + ½\, \beta_{22}(\log P_2)^2 \\
& + ½\, \beta_{33} (\log P_3)^2 + ½\, \beta_{44} (\log P_4)^2 + ½\, \beta_{55} (\log P_5)^2 \\
& + \beta_{12} (\log P_1)(\log P_2) + \beta_{13} (\log P_1)(\log P_3) + \beta_{14} (\log P_1)(\log P_4) \\
& + \beta_{15} (\log P_1)(\log P_5) + \beta_{23} (\log P_2)(\log P_3) + \beta_{24} (\log P_2)(\log P_4) \\
& + \beta_{25} (\log P_2)(\log P_5) + \beta_{34} (\log P_3)(\log P_4) + \beta_{35} (\log P_3)(\log P_5) + \beta_{45} (\log P_4)(\log P_5) + u \quad \text{------- (1)}
\end{aligned}
$$

Where,
C = Per acre Cost of Cultivation (₹),
Y = Value of per acre Output Energy (₹),
P_1 = Price per unit of Human Energy (₹),
P_2 = Price per unit of Bullock Energy (₹),
P_3 = Price per unit of Fertilizer Energy (₹),
P_4 = Price per unit of Pesticide Energy (₹) and
P_5 = Price per unit of Mechanical Energy (₹).
Using Shephard's lemma, we can derive the cost-share equation for the energy inputs:

$$S_i = \alpha_i + \beta_{i1} \log P_1 + \beta_{i2} \log P_2 + \beta_{i3} \log P_3 + \beta_{i4} \log P_4 + \beta_{i5} \log P_5 \text{ ----- (2)}$$

Where,
i = 1, 2...,5
S_i = Share of i^{th} energy input in the cost of cultivation.
The above equations (1) and (2) were jointly estimated by using Zellner's Seemingly Unrelated Regression which asymptotically presents more efficient estimates than ordinary least square method.
The coefficients thus estimated are used to compute Allen Elasticities of Substitution and price elasticities of demand for inputs. The Allen Elasticities of Substitution σ_{ij} between i^{th} energy input and j^{th} input are computed as :

$$\left.\begin{aligned} \sigma_{ij} &= (\beta_{ij} + S_i S_j) \;/\; S_i S_j \quad i \# j \\ \sigma_{ii} &= [\beta_{ii} + S_i(S_i - 1) \;/\; S_i^2 \end{aligned}\right] \quad (3)$$

The own and cross price elasticities of demand are given by :

$$\left.\begin{aligned} n_{ij} &= S_j \;\; \sigma_{ij} \text{ for } i \# j \\ n_{ii} &= S_i \;\; \sigma_{ii} \text{ for } i = j \end{aligned}\right] \quad (4)$$

The standard errors of the elasticities are estimated as :

$$\left.\begin{aligned} Var(\sigma_{ij}) &= Var(\beta_{ij}) \;/\; S_i^2 S_j^2 \\ Var(\sigma_{ii}) &= Var(\beta_{ii}) \;/\; S_i^4 \end{aligned}\right] \quad (5)$$

RESULTS AND DISCUSSIONS

The estimated results of model (1) for small, larger farmers and pooled category are furnished in the Table 1.
It is observed from the Table 1 that the cost of cultivation of MCU-5 variety of cotton in the case of small farmers was found to increase with an increase in the prices of energy inputs. Among five price variables included in the translog cost function model, three variables - namely price of human energy, fertilizer energy and mechanical energy are found to be significant at the 5 per cent level. It implies that for one per cent increase in their respective prices, the cost of cultivation of cotton could be increased by 0.8569 per cent, 0.4128 per cent and 0.7218 per cent respectively. It is inferred from the results that the price of human energy had a greater impact on the cost of cultivation of cotton in the

Table 1: Estimated Results of Translog Cost Function of Small Farmers, Large Farmers and Pooled Category of Production of The MCU-5 Cotton Variety				
Variable	**Parameter**	**Small Farmer**	**Large Farmer**	**Pooled Category**
Intercept	α_0	0.2713	0.31792	0.1585
Log P_1	α_1	0.8569* (3.6494)	0.6977* (2.0714)	0.7969* (2.0254)
Log P_2	α_2	0.0536 (0.0285)	0.0308 (0.0951)	0.1441 (0.1303)
Log P_3	α_3	0.4128* (2.5121)	0.4161* (4.2359)	0.3201* (2.2948)
Log P_4	α_4	0.0289 (0.0499)	0.0718 (0.0183)	0.0185 (0.0102)
Log P_5	α_5	0.7218* (4.1631)	0.7269* (3.5781)	0.8089* (2.6150)
Log Y	α_6	0.4523* (2.4730)	0.3218* (2.8705)	0.2148* (3.7193)
$(\log P_1)^2$	½ β_{11}	0.3188 (0.7112)	0.2067 (0.5616)	0.1818 (0.6187)
$(\log P_2)^2$	½ β_{22}	0.0359 (0.0682)	0.0488 (1.8179)	0.0184 (0.0065)
$(\log P_3)^2$	½ β_{33}	0.1769 (0.5491)	0.7851 (1.4661)	0.1496 (1.3172)
$(\log P_4)^2$	½ β_{44}	0.3241 (1.0649)	0.4632 (1.4572)	0.2249 (1.2176)
$(\log P_5)^2$	½ β_{55}	0.0198 (0.0102)	0.0974 (0.3651)	0.0678 (1.7645)
$(\log P_1)(\log P_2)$	β_{12}	0.1869 (0.0428)	0.1887 (1.3981)	0.1827 (1.2837)
$(\log P_1)(\log P_3)$	β_{13}	0.1083 (0.2993)	0.0915 (0.0166)	0.1846 (1.7849)
$(\log P_1)(\log P_4)$	β_{14}	0.1471 (1.6281)	0.1937 (0.0507)	0.2012 (1.7824)
$(\log P_1)(\log P_5)$	β_{15}	0.4261 (1.4822)	0.2817 (1.4218)	0.1112 (1.0621)
$(\log P_2)(\log P_3)$	β_{23}	0.3604 (0.3222)	0.2469 (1.3526)	0.0194 (0.0896)
$(\log P_2)(\log P_4)$	β_{24}	0.0754 (0.0432)	0.1768 (0.3218)	0.0614 (0.0412)
$(\log P_2)(\log P_5)$	β_{25}	0.1629 (1.3238)	0.2724 (1.3929)	0.242 (1.341)
$(\log P_3)(\log P_4)$	β_{34}	0.1908 (1.6854)	0.1699 (1.2156)	0.1729 (1.2198)
$(\log P_3)(\log P_5)$	β_{35}	0.0291 (1.6433)	0.0259 (1.4268)	0.0192 (1.6415)
$(\log P_4)(\log P_5)$	β_{45}	0.0291 (0.3641)	0.1476 (1.3184)	0.1492 (1.1196)
R^2		**0.78922**	**0.9052**	**0.89628**
F-Value		**27.3487**	**32.1468**	**28.9471**
No. of observations		**100**	**100**	**200**

Source: Survey data

Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level

case of small farmers. A positive relationship was also found between cost and output. An additional percentage made in the output of cotton was observed to increase its cost of cultivation by 0.4523 per cent.

In the case of large farmers producing MCU-5 variety of cotton, out of five price variables incorporated in the model, three variables namely - human energy, fertilizer energy and mechanical energy are statistically significant at 5 per cent level. It indicates that one per cent increase in the price of these energy inputs could effect 0.6977 per cent, 0.4161 per cent and 0.7269 per cent increase respectively in the cost of cultivation. The impact of a change in price of mechanical energy on cost was observed to be greater than those of the other energy inputs. It is also inferred that there was a positive relationship between cost and output. An additional percentage made in the output of cotton could increase its cost of cultivation by 0.3218 per cent. Thus, it is also observed from the analysis that cost per unit of producing cotton was found to be higher in the case of small farmers than large farmers.

In the pooled category, mechanical energy had a greater impact on the cost of cultivation of MCU-5 variety of cotton in the study area. A positive relationship was observed between cost and output.

SUBSTITUTION BETWEEN ENERGY INPUTS

The substitution possibilities of different energy inputs were computed for small and large farmers producing MCU-5 and LRA-5166 varieties of cotton.

The estimated results of Allen Elasticity of Substitution for small farmers producing MCU-5 cotton variety are furnished in the Table 2.

Table 2: Allen Elasticities of Substitution Between Energy Inputs Used in The MCU-5 Cotton Production of Small Farmers

Energy Inputs	Human Energy	Bullock Energy	Fertilizer Energy	Pesticide Energy	Mechanical Energy
Human Energy	-1.2485* (9.7286)				
Bullock Energy	-4.368 (0.9856)	-3.3482* (2.4112)			
Fertilizer Energy	1.9852 (1.4748)	5.3238 (1.4872)	-2.7618* (6.4343)		
Pesticide Energy	0.7281 (0.9812)	2.3464 (1.0791)	-6.7213* (3.4136)	-5.3461* (6.31478)	
Mechanical Energy	43.7278* (8.7459)	7.4253 (0.9820)	-4.3264 (0.8190)	0.6713 (0.0635)	-12.622* (4.720)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

It is observed from the Table 2 that the computed elasticities of substitution have the expected sign, but they are significant only for a few energy inputs . The positive and significant relationship was found between human energy and mechanical energy. It indicates that these two inputs can be substituted. This is an important result in view of the emerging trend of mechanization of agricultural products, particularly cotton cultivation in the study area. Further, the results shows the existence of complementarity of fertilizer energy with pesticide energy. It implies that a higher dose of fertilizer application may considerably reduce the use of pesticides in the cotton cultivation of MCU-5 variety. The elasticities of other sources are positive, but non-significant.

The estimated results of Allen Elasticities of Substitution for large farmers producing MCU-5 variety of cotton are presented in the Table 3.

Table 3: Allen Elasticities of Substitution Between Energy Inputs Used In The MCU-5 Cotton Production of Large Farmers

Energy Inputs	Human Energy	Bullock Energy	Fertilizer Energy	Pesticide Energy	Mechanical Energy
Human Energy	-3.4723* (6.3715)				
Bullock Energy	-12.17 (0.8178)	-6.3625* (5.1134)			
Fertilizer Energy	7.3262 (0.7835)	3.4783 (1.2116)	-10.3072* (4.6308)		
Pesticide Energy	4.0437 (1.4714)	9.1028 (1.1129)	7.8617* (6.4812)	-12.0138* (9.8736)	
Mechanical Energy	3.4727 (0.0719)	11.4717 (0.6370)	-3.3219* (7.495)	0.4736 (0.8717)	-8.4729 (4.7321)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

It is understood from the Table 3 that a positive significant relationship between fertilizers and pesticides indicates that these two energy inputs are substitutes. A negative significant elasticity of substitution was found between mechanical energy and fertilizer energy. It indicates the complementarity between mechanical and fertilizer energy. This may be due to a higher use of tractors necessitated by fertilizer-induced increase in cotton productivity in the case of large farmers producing the MCU-5 cotton variety.

PRICE ELASTICITIES OF DEMAND FOR ENERGY INPUTS (MCU-5)

The price elasticities of demand for energy inputs, derived by using the relation (4), are presented in the Tables 4 and 5 for small and large farmers producing MCU-5 variety of cotton. The estimated cross price elasticities presented in the

Table 4: Price Elasticities of Demand For Energy Inputs of Small Farmers Producing The MCU-5 Variety of Cotton					
Demand for Energy Inputs	**Price of Energy Inputs**				
	Human Energy	**Bullock Energy**	**Fertilizer Energy**	**Pesticide Energy**	**Mechanical Energy**
Human Energy	-0.4318* (8.4273)	-0.2772 (1.2726)	-0.2329* (7.4215)	0.3748 (1.0135)	0.3571* (13.6751)
Bullock Energy	-6.7428 (0.9785)	-2.4784* (9.7417)	2.1618 (1.1231)	0.4724 (0.7228)	3.6781 (0.3651)
Fertilizer Energy	0.6748 (0.0385)	0.5625 (1.0129)	-1.6791* (12.36721)	-2.3718 (0.9412)	-0.6122 (1.0032)
Pesticide Energy	0.5129 (1.0313)	0.3772 (0.0379)	0.2964 (0.0089)	-1.9759* (1.3719)	0.4371 (1.2791)
Mechanical Energy	0.2764* (6.7262)	0.4171* (8.3628)	-0.9126 (0.7217)	-0.2715 (0.3808)	-6.3253* (10.6347)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

Table 4 reveals that all own price elasticities have negative signs and are statistically significant at the 5 per cent level. The highest own price elasticity of demand is observed for mechanical energy, followed by bullock energy. The own price elasticity of human energy is less than unity, indicating the necessity of human energy in all operations.

The cross price elasticity of human and mechanical energy reveals a positive price elasticity of demand. It indicates that 10 per cent rise in price of human energy leads to a rise in demand for mechanical energy and vice-versa. The cross price elasticities of human and fertilizer energies indicate a high price elasticity. A 10 per cent increase in the fertilizer price leads to more than 20 per cent fall in demand for labour. The estimated results of price elasticity of demand for large farmers producing the MCU-5 variety are given in the Table 5.

Table 5: Price Elasticity of Demand For Energy Inputs of Large Farmers Producing The MCU-5 Variety of Cotton					
Demand for Energy Inputs		**Price of Energy Inputs**			
	Human Energy	**Bullock Energy**	**Fertilizer Energy**	**Pesticide Energy**	**Mechanical Energy**
Human Energy	-0.2363* (4.3158)	-0.4821 (0.4172)	1.1172* (10.0719)	0.2617 (1.4323)	-1.1684* (12.3424)
Bullock Energy	-6.8175 (1.1177)	-2.9816* (6.7283)	2.0315 (1.329)	0.5428 (1.0084)	3.4116 (1.3122)
Fertilizer Energy	0.4719 (0.9781)	0.3973 (1.6418)	-1.4742* (8.3717)	-1.1176 (0.7328)	-0.5628 (1.2074)
Pesticide Energy	0.3116 (0.6738)	0.2970 (0.3242)	-0.5219 (1.0113)	-1.5768* (3.4874)	0.7319 (0.7428)
Mechanical Energy	-1.2775* (4.9485)	-1.1325* (3.7302)	-0.6125 (0.07811)	-0.2780 (0.0630)	-6.7887* (9.6834)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

From the Table 5, it is found that all own price elasticities of demand are negative, and they are statistically significant at the 5 per cent level. The highest own price elasticity was found for mechanical energy, followed by bullock energy, pesticide energy and fertilizer energy. Higher own price elasticity of mechanical energy may be possible as there is sufficient time for pre-seeding operation for cotton. In the case of large farmers also, it was observed that the own price elasticity of demand was less than unity. Cross price elasticities of human energy-fertilizer energy, mechanical - human energy, and mechanical - bullock energy reveal high price elasticity. For a 10 per cent increase in mechanical energy, there is a fall in demand for labour by more than 10 per cent. A ten per cent increase in the price of fertilizer leads to 11.137 per cent increase in the demand for labour. Table 6 presents the estimated results of Translog cost function for small farmers, large farmers and pooled category of LRA-5166 variety of cotton.

It is inferred from the Table 6 that the cost of cultivation of small farmers producing LRA-5166 variety of cotton was found to increase with an increase in the prices of inputs, namely human energy, fertilizer energy and mechanical energy. Out of the five price variables incorporated in the model, three of them - namely human energy, fertilizer energy and mechanical energy were statistically significant at the 5 per cent level. It means that one per cent increase in these variables would effect 0.7891, 0.6029 and 0.6786 per cent increase respectively, in cost of LRA-5166 variety

Table 6: Estimated Results of Translog Cost Function of Small Farmers, Large Farmers And Pooled Category of Production of The LRA-5166 Cotton Variety				
Variable	**Parameter**	**Small Farmer**	**Large Farmer**	**Pooled Category**
Intercept	α_0	0.3117	0.2648	0.3487
log P_1	α_1	0.7891* (2.798)	0.6818* (2.714)	0.6896* (2.789)
log P_2	α_2	0.1024 (0.1617)	0.0949 (0.0714)	0.0189 (0.0841)
log P_3	α_3	0.6029* (4.3214)	0.5186* (3.4811)	0.5818* (4.8168)
log P_4	α_4	0.1017 (0.3141)	0.181 (0.3813)	0.1141 (0.1149)
log P_5	α_5	0.6786* (2.8129)	0.7191* (3.3818)	0.7694* (2.0646)
log Y	α_6	0.2474* (4.4634)	0.2142* (3.8191)	0.2124* (3.6117)
$(\log P_1)^2$	$½\beta_{11}$	0.0421 (0.0141)	0.1368 (0.4641)	0.0462 (0.0048)
$(\log P_2)^2$	$½\beta_{22}$	0.1038 (1.3146)	0.0681 (0.0658)	0.0418 (0.0819)
$(\log P_3)^2$	$½\ \beta_{33}$	0.1159 (0.0819)	0.1092 (1.9161)	0.1196 (0.9164)
$(\log P_4)^2$	$½\beta_{44}$	0.2169 (0.6896)	0.2089 (0.7871)	0.2149* (2.8014)
$(\log P5)^2$	$½\beta_{55}$	0.1147 (0.8174)	0.1689 (0.3159)	0.1074 (0.8149)
$(\log P_1)(\log P_2)$	β_{12}	0.0148 (0.0089)	0.0867* (2.4647)	0.0478 (0.0789)
$(\log P_1)(\log P_3)$	β_{13}	0.2357* (2.6421)	0.1914 (3.8149)	0.0789 (0.0941)
$(\log P_1)(\log P_4)$	β_{14}	0.0149 (1.3148)	0.441 (0.0469)	0.0141 (0.0691)
$(\log P_1)\ (\log P_5)$	β_{15}	0.0891 (0.0190)	0.1217* (3.8191)	0.1228* (4.7149)
$(\log P_2)\ (\log P_3)$	β_{23}	0.1117 (0.0819)	0.0891 (0.0191)	0.0169 (0.0690)
$(\log P_2)\ (\log P_4)$	β_{24}	0.2189 (1.0089)	0.2096 (0.9089)	0.1089 (0.0096)
$(\log P_2)\ (\log P_5)$	β_{25}	0.0197 (0.0891)	0.0189 (0.0569)	0.0189 (0.3019)
$(\log P_3)\ (\log P_4)$	β_{34}	0.1193* (3.0319)	0.1217* (4.6241)	0.0247 (1.6321)
$(\log P_3)\ (\log P_5)$	β_{35}	1.2171 (0.1217)	0.1621 (0.0241)	0.0142 (0.0121)
$(\log P_4)\ (\log P_5)$	β_{45}	0.1129 (0.2157)	0.14211 (1.7489)	0.1249 (1.0241)
R^2		**0.8721**	**0.9149**	**0.9179**
F-Value		**30.6542**	**47.5469**	**34.6861**
No. of observations		**100**	**100**	**200**

Source: Survey data

Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level

of cotton. It is noted that a change in human energy price on cost was higher than that of other inputs. It is observed from the analysis that a positive relationship between cost and output was found in the study area. It indicates that an additional percentage in the output of cotton could increase its cost of cultivation by 0.2474 per cent. From the results of the estimated model, cross price terms cannot be directly interpreted, and it is computed separately by using Allen Elasticities of Substitution.

In the case of large farmers producing LRA-5166 variety of cotton, out of five price variables, three variables namely, human energy, fertilizer energy and mechanical energy are found to be statistically significant at the 5 per cent level. An addition made to these variables, cost of cultivation could be increased by 0.6818 per cent, 0.5186 per cent and 0.7191 per cent respectively. It is inferred that the impact of a change in mechanical energy price on cost was found to be higher compared to other significant energy inputs. As in the case of small farmers, output is positively related to its cost of cultivation in the case of large farmers also.

In the case of pooled category, three out of five price variables namely - human energy, fertilizer energy and mechanical energy are statistically significant and are positively related to the cost of cultivation of LRA-5166 variety of cotton in the study area. Price of mechanical energy had a greater impact on cost of cultivation of cotton in the study area. There was a positive relationship between cost and output.

ALLEN ELASTICITIES OF SUBSTITUTION (LRA-5166)

The estimates of Allen Elasticity of Substitution for various energy inputs for small farmers producing LRA-5166 variety of cotton are presented in the Table 7.

Table 7: Allen Elasticities of Substitution Between Energy Inputs Used in The LRA -5166 Cotton Production of Small Farmers

Energy Inputs	Human Energy	Bullock Energy	Fertilizer Energy	Pesticide Energy	Mechanical Energy
Human Energy	-3.4714* (6.3218)				
Bullock Energy	6.7214 (0.7428)	-10.3716* (8.9171)			
Fertilizer Energy	3.4785 (0.9829)	7.6217 (0.3123)	-5.7287* (9.6428)		
Pesticide Energy	0.4808 (1.0717)	3.6729 (1.1424)	8.3672* (6.7313)	-4.6731* (13.7824)	
Mechanical Energy	6.6725* (4.7214)	4.8316* (6.1217)	-6.1717* (4.3235)	0.9427 (0.0328)	-8.3263* (10.1730)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

It is understood from the Table 7 that the elasticities of substitution between human energy and mechanical energy, bullock energy and mechanical energy and pesticide energy and fertilizer energy are positive and significant, indicating that they are substitutes. The elasticities of other sources notably human - pesticide, human -bullock energies are positive, but non-significant.

The computed results of Allen Elasticities of Substitution for large farmers producing LRA-5166 are given in the Table 8.

Table 8: Allen Elasticities of Substitution Between Energy Inputs Used In The LRA-5166 Cotton Production of Large Farmers

Energy Inputs	Human Energy	Bullock Energy	Fertilizer Energy	Pesticide Energy	Mechanical Energy
Human Energy	-6.7262* (10.7217)				
Bullock Energy	-4.6382 (1.1219)	-9.4729* (12.6315)			
Fertilizer Energy	-2.0127* (6.4726)	6.3148 (1.2142)	-12.6723* (8.7217)		
Pesticide Energy	1.0635 (0.7816)	3.4787 (0.6315)	5.3613* (3.7271)	-4.3618* (6.3178)	
Mechanical Energy	6.0428* (10.0771)	5.3617* (9.4812)	-3.3985 (1.1187)	1.1258 (0.7815)	-14.6789* (9.4926)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

It is inferred from the Table 8 that the computed elasticities of substitution have the expected sign, but very few energy inputs are statistically significant. The elasticity of substitution between human energy and mechanical energy, bullock energy and mechanical energy are positive and significant. It indicates that they are substitutes in the case of large farmers producing LRA-5166 variety of cotton in the study area. The elasticity of substitution between human energy and fertilizer energy was found to be negative and significant and it indicates the complementarity between these two sources of energy. P. Binswanger and G. Subramaniyan in their studies have reported a significant complementarity between human energy and fertilizer energy.

PRICE ELASTICITIES OF DEMAND FOR ENERGY INPUTS

The estimated price elasticities of demand for small farmers producing LRA-5166 variety of cotton are furnished in the Table 9.

Table 9: Price Elasticities of Demand For Energy Inputs of Small Farmers Producing The LRA-5166 Variety of Cotton					
Demand for Energy Inputs	**Price of Energy Inputs**				
	Human Energy	**Bullock Energy**	**Fertilizer Energy**	**Pesticide Energy**	**Mechanical Energy**
Human Energy	-0.7318* (4.7126)	-0.5719 (0.6408)	-0.4848* (12.6716)	0.3419 (1.0418)	0.9481 (9.4762)
Bullock Energy	-7.652 (1.0717)	-3.6785* (10.0719)	1.0609* (10.7818)	0.6121 (0.0719)	4.8371 (1.0452)
Fertilizer Energy	0.7814 (0.9812)	0.4113 (0.7822)	-1.4371 (6.4796)	-1.0718 (1.9114)	-0.4057 (1.4741)
Pesticide Energy	0.4308 (1.1215)	0.3018 (1.3786)	-0.6303 (0.4715)	-1.34342* (7.8296)	0.1371 (0.9461)
Mechanical Energy	0.8909* (4.7426)	0.4511* (6.9452)	-0.7406 (0.7412)	-0.3411 (1.0422)	-4.8987* (12.7335)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

It is observed from the Table 9 that all own price elasticities of demand have negative signs and are statistically significant at the 5 per cent level. Energy demand, except human energy, from all other energy inputs, is price elastic. The highest own price elasticity of demand was observed for mechanical energy followed by bullock energy. The cross price elasticity of human-fertilizer energy reveals complementarity between these two input energies. Human-mechanical energy and bullock-mechanical energy have positive price elasticity and they are statistically significant. It indicates that a rise in price of human and bullock energies leads to a rise in demand for mechanical energy. This again confirms the substitutability between human-mechanical, bullocks - mechanical energies.

The Table 10 shows the own and cross price elasticity of demand for large farmers producing the LRA-5166 variety of cotton.

Table 10: Price Elasticities of Demand For Energy Inputs of Large Farmers Producing The LRA-5166 Variety of Cotton					
Demand for Energy Inputs	**Price of Energy Inputs**				
	Human Energy	**Bullock Energy**	**Fertilizer Energy**	**Pesticide Energy**	**Mechanical Energy**
Human Energy	-0.4919 (3.7525)	-0.7824 (0.0733)	0.5662* (4.7216)	0.4329 (1.0112)	0.9784* (4.7214)
Bullock Energy	5.3438 (2.5373)	-4.3242* (5.9838)	2.0618* (6.4716)	0.5413 (0.9241)	3.4723 (1.0487)
Fertilizer Energy	0.7192 (0.0836)	0.3735 (1.0073)	-2.6890* (10.4795)	-1.0736 (0.6321)	-0.3814 (0.4770)
Pesticide Energy	0.3675 (1.2782)	0.2975 (0.6727)	-0.7262 (0.3828)	-2.0471* (9.5276)	0.968 (0.1428)
Mechanical Energy	0.9127* (10.7256)	0.5117 (1.1128)	-0.6829 (1.01242)	-0.4125 (0.4723)	-2.9419* (12.4724)
Source: Survey data					
Note: Figures in brackets represent t-values, * Indicates significance at 5 per cent level					

From the Table 10, it is seen that the own price elasticities of all energy inputs are negative, indicating that any rise in their prices would negatively affect their demand. A 10 per cent increase in bullock energy, fertilizer energy, pesticides energy and mechanical energy was observed to result in more than 20 per cent decrease in their demand. It indicates that demand for these energy inputs are highly price elastic. The cross price elasticity of human and mechanical energy was positive, indicating that a rise in the price of human energy leads to a rise in demand for mechanical energy and vice versa. It confirms the result of substitutability between human and mechanical energies.

SUMMARY

The findings of the above analysis are summarized as follows:

- The analysis of substitution and complementarity between energy inputs reveals that human and mechanical energy were substitutes in the case of small farmers producing MCU-5 cotton variety. The paper confirms the existence of complementarity between fertilizer energy and pesticide energy. In the case of large farmers producing the MCU-5 variety, complementarity between mechanical and fertilizer energy was observed.

☸The estimated results of Allen Elasticity of Substitution indicated that substitution between human energy - mechanical energy, bullock energy - mechanical energy, and pesticide energy - fertilizer energy was established in the case of small farmers. Elasticity of substitution between human energy- mechanical energy, and bullock energy - mechanical energy was found to be significant. Complementarity was found between human energy and fertilizer energy in the case of large farmers.

☸The estimated results of *'own and cross price elasticity of demand'* revealed that own price elasticity of human energy was less than unity, indicating the necessity of human energy in all operations in the case of small farmers producing the MCU-5 variety of cotton. The cross price elasticity showed that there was a positive price elasticity of demand between human and mechanical energies and human and fertilizer energies.

☸In the case of large farmers producing the MCU-5 variety, the highest own price elasticity was found for mechanical energy in the study area. Own price elasticity of demand was found to be less than unity in all energy inputs. High cross price elasticity was found for human and fertilizer energy, mechanical and human energy, and mechanical and bullock energy.

☸In case of the LRA-5166 variety, energy demand (except human energy) from all other energy inputs was price elastic. The highest own price elasticity was observed for mechanical energy in the case of small farmers. The significant cross price elasticity was found between human – mechanical energy and bullock – mechanical energy. It indicated that an increase in price of human and bullock energy led to an increase in demand for mechanical energy.

Thus, it confirmed the substitutability between human – mechanical energy and bullock – mechanical energy.
In the case of large farmers, the negative own price elasticities indicated high price elasticity. The estimated results of cross price elasticities of human energy and mechanical energy indicates the substitutability between human and mechanical energy.

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