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Full Length Research Paper

Input Demand Response Analysis of Wine Grape Farmers in Dodoma City and Chamwino District in Dodoma Region, Tanzania: Application of the Profit Function

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Abstract

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The study analysed factor demand response of smallholder wine grape farmers. Maximum Likelihood Method was used to estimate profit function while Ordinary Least Square was used to estimate demand function. A multistage and random sampling method was used to obtain 176 farmers under irrigation and 183 farmers under rain fed production. A cross-sectional data was used. Results indicate that estimated short run factor demand responses for labour, manure and agrochemicals were price inelastic, implying that in a short run farmer`s input demand does not quickly adjust to changes in their own input prices. Results also reveal that two pairs of inputs *i.e.,* agrochemical and manure as well as labour and manure had a complementary relationship, while labour and agrochemical had a substitute relationship. It is therefore recommended that any policy measures targeting on reducing fertilizer, labour and agrochemical price would improve grape productivity and hence increase farmer`s income. It is also important to strengthen farmer`s knowledge and skills on agrochemical and manure application for wine grape farming because these inputs have a joint effect on improving wine grape productivity and profit among farmers.

Keywords: Wine grape, profit function, factor demand response, price elasticities.

INTRODUCTION

Grape (*Vitis Vinifera L.*) is an important economic fruit crop in Dodoma Region. It is one of the crops with greatest potential to contribute in poverty reduction in the region through its wide range of activities and usage. In term of usage, grapes can be consumed both as fresh and processed products such as wine, juice, dried grapes, jam and vinegar. Around 50% of world grapes production is used for making wine, 36% are consumed as fresh fruits, 6% are used for making juice and 8% are dried to make raisins (FAO and OIV, 2016). In terms of economical

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contribution, grape cultivation plays important role to households and Dodoma region`s economy. For example, in 2015 grape cultivation contributes about 36% of household income among grape farmers particularly in Dodoma City (Lwelamira *et al.,* 2015a). Grape cultivation provides direct employment to about 1700 households and also benefits indirectly the livelihood of about 7800 beneficiaries at the farm level (Robbins, 2016). This figure does not include a number of people involved in the value chain such as trading, transportation, processing and packaging.

In addition, grape subsector provides substantial raw materials for local winery, juice, jam and vinegar processing industries, hence it is particularly poised to contribute to the contemporary Tanzania national agenda of pushing the national economy from low to middle income economy through industrialization because it creates another avenue for employment opportunities. Despite these numerous economic benefits of grapes, grape cultivation in Dodoma faces the challenge of high input price variability, unreliable market for output and low output prices (Lwelamira *et al.,* 2015a; Kulwijila *et al.,* 2018). For example between 2010 and 2016, cost of production rose from TZS 290 000 to TZS 730 000 per ton of grapes, while grape prices remained relatively low, ranging from TZS 500 to 1200 per kilogram of grapes (Lwelamira *et al.,* 2015a; LWR, 2016). These high input prices and low output prices are main shocks, which reduces input usage among smallholder wine grape farmers because rising cost of input reduces farmer`s purchasing power, consequently affects resource use such as agrochemicals (Junaid *et al.,* 2014). Currently status of fertilizer application rate in Tanzania is lower 19.3 kg/hectare compared to other countries in Africa (Lema *et al.,* 2014). For example, Kenya and south Africa`s fertilizer application rates are 100 kg/ha and 20kg/ha respectively. Low rate of fertilizer application in Tanzania is attributed by high fertilizer prices as such most smallholder farmers do not have capacity to purchase fertilizer (Lema *et al.,* 2014; Bonilla Cedrez *et al.,* 2020). This leads to low farm productivity in most of agricultural crops, including wine grapes (average yield of 5.6 ton/ha compared to the established yield potential of 25 ton/ha under irrigation and 17.3 ton/ha under rain-fed in Tanzania (Robbins, 2016). As such reducing farmers production cost is of paramount important to increase farm productivity and income. Thus, in order to increase productivity and farm income effective pricing policy should be in place to regulate input prices thereby reducing cost of production (Mustafa *et al.,* 2016). However, formulating an effective pricing policy requires reliable empirical knowledge about degree of responsiveness of factor demand and output supply due to change in factor prices. The study therefore aimed at analysing factor demand response due to change in factor prices in order to provide valuable information to policy-makers who seek to reduce wine grape production cost for the purpose of increasing farm productivity.

Theoretical Framework

Microeconomic theory suggests that major determinants of output supply and factors demand include its own prices, price of close substitute products or inputs and complementary input/output. An output supply function describes how the quantity of produce offered for sale varies due to variation in own price and price of related commodities, while a factor demand function describes how demand for an input varies due to change in its own factor price and the price of related inputs (Junaid *et al.,* 2012). Under the profit maximization assumption in a competitive market structure, factor demand and output supply function can be derived directly from a profit function using Hotelling`s lemma, according to which, the first derivative of a profit function with respect to input and output prices give the profit maximising level of output supply and factor demand functions, which are expressed in terms of input and output prices (Debertin, 2012; Thakare *et al.,* 2012; Mailena *et al.,* 2013). Moreover, the second derivate of profit function with respect to input and output prices provide factor demand elasticities. The factor demand elasticity is therefore refers to a degree of responsiveness of input use due to changes in its factor price and the price of other input as well as the price of output. This usually gives two type of factor demand elasticity namely; (i) Own factor price elasticity and (ii) Cross factor price elasticity. Own factor price elasticity measures the extent to which framers vary their purchases as the factor price changes, while cross factor price elasticity measures degree of responsiveness of factor demand due to change in price of other inputs (Ullah *et al.,* 2012; Junaid *et al.,* 2014).

Usually, the profit function must meet the following properties (i) non-decreasing in output price; (ii) non-increasing in input prices for given fixed factors; and (iii) homogenous[1] of degree one in fixed factor for given input and output prices (Trong and Napasintuwong, 2015). Hence, farm profit (π_i) is determined as the difference between total revenue and total cost, whereas total cost involve total variable cost and total fixed cost as presented in equation 1.

[1]Homogeneous of degree 1 was imposed by normalizing profit and input prices by output price

$$\pi_i = y_i p_y - \sum_{i=1}^{n} v_i x_i - TFC_i \quad (1)$$

Where

$\pi_i =$ is profit of i^th^ farmer; $y_i =$ Total output of i^th^ farmer; $P_y =$ Average price of output of i^th^ farmer; $y_i p_{yi} =$ Total revenue; $v_i x_i =$ Total variable cost (labour cost computed based annual farm management activities, insecticides, fungicide and manure); $v_i =$ Price of variable input x_i; $x_i =$ Variable input;- and $TFC_i =$ Total fixed cost of i^th^ farmers (including annual capital recovery cost plus depreciation of farm tools).

The normalized profit function is given as

$$\pi_i^* = \frac{\pi}{P_y} = y_i - \frac{\sum_{i=1}^{n} v_i x_i - TFC}{P_y} = f(X_i, Z) - \sum_{i=1}^{n} P_i X_i - Z_i \quad (2)$$

Where

$\pi^* = \pi / p_y$ Represents the normalized profit of i^th^ farmer; $P_y =$ Output prices used to normalize variables in the equation 1; $X_i =$ Represents optimal quantity of input; $Z =$ Represent fixed factor; $P_i = v_i / P_y =$ Normalized price of input X_i; $f(X, Z) =$ Production function and other variables are as defined earlier. Adopting Rahman (2003) model, equation 2 can be presented as follows: -

$$\pi^{\bullet} = f(P_i, Z_i)\exp\varepsilon_i \quad (3)$$

Where; ε_i is a composite error consisting of two independent elements "v_i" and "μ_i", and $i = 1,2...n$ number of farms in the sample.

The indirect input demand functions can be obtained by taking the first derivative of the profit function (equation 3) using Hotelling`s lemma, which gives the equation twelve (4).

$$\frac{\partial \pi_i^*}{\partial P_i} = \frac{\partial \pi(P_i, Z_i)}{\partial P_i} = X_i(P_i, Z_i) \quad (4)$$

Or

$$X_i^{\bullet} = X_i(P_i, P_j, Z_i) \quad (5)$$

Where;

$\pi_i^* =$ The normalized profit of i^th^ farmer as described in page 20 of this study; $X_i^{\bullet} =$ Represents the quantity of i^th^ input demanded in kilogram; $P_i =$ Price of input x_i divided by price of output in TZS; $P_j =$ Price of input x_j divided by price of output in TZS; $Z_i =$ is vector of fixed inputs; and $i \neq j =$ Represents number of inputs

This derivative provides a system of factor demand equations with respects to factor prices. Since a profit function is homogeneous of degree one, these demand equations are homogeneous of degree zero[2] in input prices. Assuming that a profit function is convex, the proposition of profit maximization behaviour can be derived as follows;-

$$-\frac{\partial X_i}{\partial P_i} = \frac{\partial}{\partial P_i}\left(\frac{\partial \pi(P_i, Z_i)}{\partial P_i}\right) = -\frac{\partial^2 \pi(P_i, Z_i)}{\partial p_i^2} \quad (6)$$

This gives the input's own factor demand price elasticity, which is always negative, economic interpretation is that, if the absolute value of an input`s own price elasticity is less than unit $\left(\frac{\partial X_i}{\partial P_i} = |\ell_p| < 1\right)$, it implies that the factor demand is inelastic, while if the value is greater than unit $\left(\frac{\partial X_i}{\partial P_i} = |\ell_p| > 1\right)$, that factor demand is elastic.

Moreover, the derivative of the input demand function with respects to price of other related inputs provide cross-factor price elasticities. The cross-factor price elasticity is described in equation 15.

$$\frac{\partial X_i(P_i, Z_i)}{\partial P_j} = \frac{\partial}{\partial P_j}\left(\frac{-\partial \pi(P_i, Z_i)}{\partial P_i}\right) = \frac{\partial}{\partial P_i}\left(\frac{-\partial \pi(P_i, Z_i)}{\partial P_j}\right) = \frac{\partial X_i(P_i, Z_i)}{\partial P_j} \quad (7)$$

The economic interpretation is that if the value of the cross-factor price elasticity is less than zero

[2] Because profit function is continuously differentiable and homogenous of degree one, then its first derivative is homogenous of degree c-1.

$\left(\frac{\partial X_i}{\partial P_j} < 0\right)$, then the demand for two inputs X_i and X_j is said to be complementary, but if the value of the cross-factor price elasticity is positive $\left(\frac{\partial X_i}{\partial P_j} > 0\right)$, then the demand for two inputs X_i and X_j is said to be substitutes.

The null hypothesis of factor demand response is stated that changes in the price of labour, manure and agrochemical do not influence the demand for corresponding own inputs and other related inputs. Mathematically is presented as $(H_0 : \partial X_i^* / \partial p_i = \partial X_i^* / \partial P_j = 0)$. Where $\partial X_i^* / \partial p_i$ = change in factor demand due to change in own factor price; $\partial X_i^* / \partial P_j =$ change in factor demand due to change in price of other factors and $i \neq j =$ represents number of inputs. The alternative hypothesis states that changes in the price of labour, manure and agrochemical influence the demand for corresponding own inputs and other related inputs $(H_a : \partial X_i^* / \partial p_i \neq \partial X_i^* / \partial P_j \neq 0)$. The empirical model specification for factor demand response analysis is presented in the methodology.

METHODOLOGY

CHARACTERISTICS OF THE STUDY AREA

The study was conducted in Dodoma City and Chamwino District because they are leading in commercial grape production in Dodoma region. Dodoma region is found in central zone of Tanzania lying between latitudes 4º and 8º South of the Equator and between longitudes 35º and 37º East of the prime meridian (Greenwich). Specifically, Dodoma City lies between latitude 5.50^0 and 6.30^0 South of the Equator and Longitude 35.30^0 and 36.02^0 East of Greenwich, while Chamwino district is located at 4.0^0 and 8.0^0 Latitude South of the Equator and between 35^0 and 37^0 Longitude East of the Greenwich (URT, 2015b; URT, 2015c). The study area is found 1100 metres above the sea level with low levels of humidity and cool breezes (Robbins, 2016). Dodoma city is characterized by urban and rural qualities, which is surrounded by scattered stony hills among them being Mlimwa, Isanga, Mkalama and Imagi. While Chamwino district is characterized by Savannah type of climate and it is surrounded by a number of mountains and a chain of hills from the Northwest to the Southwest. Both districts receive an average 570 millimetres of rainfall per annum, having two seasons namely; a short wet season, which lasts from December to mid-April and a long dry season, which starts from late April and early December. The average annual temperature varies between 20^oC in July and 30^oC in November (UNCCD, 2013; URT, 2015b; URT, 2015c). All these are pre-requisite climatic conditions for grape production. Agriculture is the predominant economic activity in both districts, employing about 90% of the active working population (URT, 2015a; URT, 2015b).

Sampling Procedure and Sample Size

The study used a cross sectional research design. Multi-stage sampling technique was used. In the first stage, purposive sampling was used to select Dodoma region, Chamwino district and Dodoma city based on their relatively high volume of commercial grape production. Moreover, Dodoma city and Chamwino district benefited from various interventions for grape expansion and productivity improvement since 1960s. In the second stage, simple random sampling was used to select wards from each district. Simple random sampling was also used to select villages or Mitaa (in Dodoma City) from each ward. Then, the grape farmers were purposely stratified into two strata differentiating farmers using irrigated farms and from those under rain-fed production technology. Further, sample frame from each stratum were ordered in a random manner to ensure representative of the total population. Finally, the farmers were selected using a systematic sampling procedure from each stratum because it is easy and cost effective to implement compared to simple random sampling. Moreover, systematic sampling procedure is more practical because it ensures more even distribution of the sample over the entire population (Kothari, 2004). A total of 359 grape farmers were selected from the sampling frame consisting of 1700 smallholder grape farmers. The sampling frame was established in collaboration with the agricultural district officials before the actual data collection. A structured questionnaire was used to collect primary data from the respondents. The instrument included questions on farming operation such as land area cultivated, number of people, hours and days used to perform farm operations, quantity of manure, agro-chemicals (insecticides, pesticides and fungicides) and total output produced. Additional information included the cost of labour, manure, agro-chemicals as well as output price. The questionnaire also contained information on socio-economic, demographic and institutional factors such as age, sex, years of schooling, farming experience, access to extension services and credit facilities.

Empirical Model Specification

A number of statistical techniques are available in the literature which are used to model factor demand response for annual and perennial crops. Most of the previous studies applied profit function to estimate factor demand response using the Seemingly Unrelated Regression Estimation (SURE) (Suriagandhi, 2011; Thakare *et al.,* 2012; Mailena *et al.*, 2013). The SURE method requires that profit functions and the system of demand functions to be jointly estimated using the Zellner (1962) estimation method (Mailena *et al.,* 2013; Rahman *et al.,* 2016). But the SURE method is asymptotically equivalent to the Maximum Likelihood Method (MLM) when iterated to convergence (Mailena *et al.,* 2013). The present study therefore used the MLM to estimate profit function and Ordinary Least Square (OLS) to estimate factor demand functions in order to obtain indirect factor price elasticities with respect to variable input prices. Assuming that the profit function is of Cobb-Douglas type, hence the Cobb-Douglas profit frontier is specified in equation 8.

$$\pi_i^* = AP_{1i}^{\beta_1} P_{2i}^{\beta_2} P_{3i}^{\beta_3} P_{4i}^{\beta_4} \ell^{\varepsilon_i} \text{.................................}(8)$$

Where $\pi_i^* =$ Profit of i^th farmers for $i = 1,2,3,...359$; $A =$ Constant terms; $P_1 =$ Cost of labour (TZS/ha) of the i^th farmer; $P_2 =$ Cost of manure (TZS/ha) of the i^th farmer; $P_3 =$ Cost agro-chemicals (TZS/ha) of the i^th farmer; $P_4 =$ Number of plant in a farm of i^th farmer; $\beta_i =$ are the parameters to be estimated; and $\varepsilon_i =$ Composite error term.

Applying Hotelling's lemma, the study derive three factor demand functions from Cobb-Douglas type profit function, as presented in equations 9-11.

i. Labour demand equation

$$-\frac{\partial \pi_i^*}{\partial P_{1i}} = -\beta_1 AP_{1i}^{\beta_1 - 1} P_{2i}^{\beta_2} P_{3i}^{\beta_3} P_{4i}^{\beta_4} \text{................................}(9)$$

ii. Manure demand equation

$$-\frac{\partial \pi_i^*}{\partial P_{2i}} = -\beta_2 AP_{1i}^{\beta_1} P_{2i}^{\beta_2 - 1} P_{3i}^{\beta_3} P_{4i}^{\beta_4} \text{................................}(10)$$

iii. Agrochemical demand equation

$$-\frac{\partial \pi_i^*}{\partial P_{3i}} = -\beta_3 AP_{1i}^{\beta_1} P_{2i}^{\beta_2} P_{3i}^{\beta_3 - 1} P_{4i}^{\beta_4} \text{................................}(11)$$

The linearized system of demand functions and profit function are presented in equations 12 -15.

The linearized Cobb-Douglas profit function

$$\ln \pi_i^* = \beta_o + \beta_1 \ln P_{1i} + \beta_2 \ln P_{2i} + \beta_3 \ln P_{3i} + \beta_4 \ln P_{4i} + v_i - \mu_i \text{..................................}(12)$$

Labour demand function

$$\ln L = -[\ln(A\beta_1) + (\beta_1 - 1)\ln P_{1i} + \beta_2 \ln P_{2i} + \beta_3 \ln P_{3i} + \beta_{4i} \ln P_{4i}] \text{..}(13)$$

Manure demand function

$$\ln M = -[\ln(A\beta_2) + \beta_1 \ln P_{1i} + (\beta_2 - 1)\ln P_{2i} + \beta_3 \ln P_{3i} + \beta_{4i} \ln P_{4i}] \text{..}(14)$$

Agrochemical demand function

$$\ln Agr = -[\ln(A\beta_3) + \beta_1 \ln P_{1i} + \beta_2 \ln P_{2i} + (\beta_3 - 1)\ln P_{3i} + \beta_{4i} \ln P_{4i}] \text{...........}(15)$$

Where: $\ln =$ Natural logarithm; $L =$ Quantity of Labour (man-day/ha); $M =$ Quantity of manure (kg/ha); and $Agr =$ Quantity of Agrochemical (kg/ha).

Data and Data Analysis

The study used cross-sectional data on quantities of output and input prices for the period of two years, *i.e.,* 2015 and 2016. The quantity produced and input prices were collected from individual farmers using structured questionnaire. Verification regarding information on inputs such as input prices and input usage were obtained from local area extension officer and input stockists. Secondary data such as total number of grape farmers, amount of rainfall and temperature were obtained from the District Council offices. The factor demand response was analysed using OLS. First stage, individual farm profit was regressed against input costs and total number of plants in the farms using MLM. Henceforth the parameter estimates of the profit function were used to compute indirect factor demand functions. The indirect factor demand functions were analysed using OLS. The results for factor demand response analysis of wine grape farmers are presented in the next section.

RESULTS AND DISCUSSION

Maximum Likelihood Estimates

The results of maximum Likelihood estimates are presented in Table 1. The results revealed that profit function is the non-increasing in input prices of labour, manure and agrochemicals. This means that increasing the cost of these variables, especially agrochemical and labour will significantly reduce profit in wine grape farming. Based on the results in Table 1, one shilling increase in labour cost would reduce wine grape profit by; 0.078 TZS under rain-fed production and by 0.036 TZS under irrigated production. The findings also showed that agrochemical cost can potentially lower the profit of wine grape farmers in the study area, implying that a one shilling increase in agrochemical costs can decrease the profit by; 0.031 TZS for irrigated and by 0.095 TZS under rain-fed production. The estimated coefficients for number of plants per hectare under irrigation and rain-fed production were all positive and statistically significant different from zero at 95% and 99% level, implying that an increase of one grapevine plant per hectare up to optimum plant population can increased profit by; 0.089 TZS under rain-fed production and by 0.054 TZS under irrigated production.

Factor demand response analysis for rain-fed farmers

The results presented in Table 2 show own and cross-factor price elasticities for labour, manure and agrochemical under rain-fed production. The findings show that the coefficient for determination of labour $(R^2 = 0.57)$ is low compared to coefficient for determination of agrochemicals $(R^2 = 0.83)$ and manure $(R^2 = 0.91)$. This means, in the short run, about 83% and 91% of variation in demand for agrochemical and manure respectively was explained by factors that are included in the models, while the rest was explained by other factors that are not included in the models. Only 57% of the variation in demand for labour was explained by the factors included in the model. Notwithstanding these variations in the coefficient for determination, the $F-$test for each model (*i.e.,* 61.3 for the labour demand, 444 for manure and 216 for agrochemical demand) was statistically significant at 1% level, implying that the models provide the best fit for the data.

The results show that own price elasticities for labour, manure and agrochemical were negative and statistically significant at 1% level (*i.e.,* -0.74 for labour, -0.95 manure and -0.80 for agrochemical), implying that an increase in price of these inputs by 1% would reduce demand for labour, manure and agrochemical by 0.74%, 0.95% and 0.80% respectively. These results were consistent with the theory of demand, which states that there is negative relationship between factor demand and factor price. This findings further suggest that in the short-run, farmer`s demand for the inputs does not quickly adjust to changes in their own input prices.

The possible explanation for this is that first, wine grape is a perishable fruit which is very much affected by insects, fungi, termites and diseases. Hence, to cope with these problems the use of agrochemical such as pesticide, insecticides and fungicides is a must; secondly, wine grape production in the study area is not mechanized hence the use of labour is inevitable; third, wine grape is a perennial crop therefore in order to realize higher productivity, manure application is of paramount important; fourth grapes is the only perennial commercial crop grown in Dodoma city and Chamwino district and wine grape farmers are price taker in input and output markets as such changes in factor prices are likely to have little influence on their decision to raise or reduce the input utilization because effect of non-price factors could have significant effects on input utilization that overrides the effect of prices. Similar finding was reported by Mailena *et al.* (2013) among rice farmers in Malaysia who reported a 1% increase in own input prices of labour and herbicides, the demand for labour and herbicides decreased.

Results also show that there is a pair of complementary and substitute inputs. For example, a pair of manure and agrochemical had a negative relationship (*i.e.,*-7.70), which was significant different from zero at 1% level $(\alpha = 0.01)$, indicating that this pair of input has complementary relationship. The findings also show that labour and manure had a negative sign (-13.52), implying that labour and manure are complementary inputs in wine grape farming. This finding is line with that of Suriagandhi (2011) and Ullah *et al.,* 2012) who found that labour and fertilizer are complementary inputs in banana and cotton production respectively. Meanwhile, the demand for labour with respect to agrochemical price was 3.84, which was statistically significant at 1% level $(\alpha = 0.01)$. This means, on average a 1% increase in agrochemical price would increase demand for labour by 3.84. This means, labour and agrochemical are substitutes, especially for weeding. In addition to the analysis of factor demand response for the rain-fed, the present study also analysed factor demand response under irrigation, as presented in the next subsection.

Factor demand response analysis for farmers under irrigation

On the basis of coefficient of determination (R^2), which was 0.74 for labour, 0.95 for farm yard manure and 0.83 for agrochemical (Table 3), implying that in the short–run the explanatory variables included in the regression model explains well the variation of the demand for

Table 1: Maximum likelihood estimates.

Stochastic profit frontier	Expected sign	Irrigated farms			Rain-fed farms		
		Coefficient	**SE**	**t-test**	**Coefficient**	**SE**	**t-test**
Intercept		29.292	4.846	6.04	6.052	1.417	4.27
Cost of labour	-ve	-0.036**	0.016	-2.26	-0.078**	0.038	-2.03
Cost of manure	-ve	-0.019	0.075	-0.26	-0.012	0.051	-0.25
Cost of agrochemical	-ve	-0.031**	0.014	-2.22	-0.095**	0.049	-1.93
Number of plants	+ve	0.054**	0.026	2.06	0.089**	0.034	2.10

Source: Computer print-out of FRONTIER 4.1 Dependent variable is the logged profit.

Note: *** implies significance at 0.01 probability level,
** implies significance at 0.05 probability level, and
* implies significance at 0.1 probability level

Table 2: Factor demand response under rain-fed

Description	Local Wage Coefficient	Price of Manure Coefficient	Price of Agrochemical Coefficient	F-test	Adjusted R^2
Labour	-0.74*** (-14.39)	-13.52*** (-4.84)	3.84*** (7.50)	61.3***	0.57
Manure	-2.00*** (-3.96)	-0.95*** (-23.75)	-0.35 (-0.97)	444***	0.91
Agrochemical	-0.68 (-1.40)	-7.70*** (-4.03)	-0.80*** (-26.34)	216***	0.83

Source: Field survey (2016) Figures in parenthesis are t-values.

Note: *** implies significance at 0.01 probability level,
** implies significance at 0.05 probability level, and
* implies significance at 0.1 probability level.

labour, manure and agrochemical. The F-statistic was 126.5 for the labour, 848.5 for farm yard manure and 213.4 for agrochemical, indicates that all models were the best fit for the data. The findings also indicate that the coefficient for own factor price elasticities for labour, manure and agrochemicals had a negative sign and were statistically significant at 1% level, which is also consistent with demand theory.

The results show that own factor elasticity was 0.86 for labour, 0.85 for manure and 0.83 for agrochemical, implying that on average a 1% increase in the price of these inputs would result to a reduction of 0.86% in the demand for labour, 0.85% in the demand for manure and 0.83% in the demand for agrochemicals. The absolute values of own price elasticities under irrigation and rain-fed were less than one, which means factor demand response due to changes in the corresponding own factor price is inelastic. This means, a greater change in own factor price would result into less than proportionate change in quantity demanded for respective factor (Junaid *et al.,* 2014). The possible explanation for this inelastic demand response are; (i) it takes longer time sometimes for the farmer to adjust to market prices because grape is a perennial cash crop, (ii) grape farming is less mechanized, hence the use of labour is inevitable, (iii) grape is a perishable fruit, which is very much affected by insects and fungi, therefore application of agrochemical is necessary, and (iv) since wine grape is a perennial crop, therefore in order to realize high productivity, manure application is of paramount important.

The results also show that demand for labour with respect to manure price had a negative sign, implying that manure and labour are complementary inputs such that this pair of input is used jointly in grape farming. For example, the factor demand response of labour with respect to manure price was -6.85, was significantly different from zero at 1% level significance $(\alpha = 0.01)$.

Table 3: Factor demand responses under irrigation.

Description	Local Wage	Price of Manure	Price of Agrochemical	F-test	Adjusted R^2
	Coefficient	Coefficient	Coefficient		
Labour	-0.86*** (-12.29)	-6.85*** (-3.90)	-1.65 (1.14)	126.5***	0.74
Manure	1.47** (2.40)	-0.85*** (-21.25)	-0.57 (-0.79)	848.5***	0.95
Agrochemical	-0.33 (-0.39)	-2.74** (2.22)	-0.83*** (-16.6)	213.4***	0.83

Source: Field survey (2016) Figures in parenthesis are t-values.
Note: *** implies significance at 0.01 probability level,
** implies significance at 0.05 probability level, and
* implies significance at 0.1 probability level

This means, on average a 1% increase in manure price would reduce the demand for labour by 6.85%. Meanwhile, demand for agrochemical with respect to manure price was -2.74, was significantly different from zero at 5% level $(\alpha = 0.05)$. This means, on average a 1% increase in manure price would reduce demand for agrochemical by 2.74%. Based on the study findings the null hypothesis of this study, which states that changes in the price of labour, manure and agrochemical do not influence the demand for corresponding own inputs and other related inputs, was rejected at 1% level. This implies that changes in the price of labour, manure and agrochemical influence the demand for corresponding own inputs price and the price of other related inputs.

Conclusion and Economic Implication

The study analysed factor demand response of smallholder wine grape farmers using profit function. Results showed that that factor demand response due to changes in own factor price is inelastic, implying that in the short-run farmer`s demand for the inputs does not quickly adjust to changes in their own input price. Moreover, results revealed that there is a pair of complementary and substitute inputs. Agrochemical and manure as well as labour and manure had a complementary relationship while labour and agrochemical had a substitute relationship. The study recommend that any policy measures targeting on reducing fertilizer, labour and agrochemical price would substantially improve wine grape productivity and profit among farmers. Also, it is important to strengthen farmer`s knowledge and skills on agrochemical and manure application for wine grape farming because these inputs have a joint effect on improving wine grape productivity and profit among farmers.

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