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Are Kenyan smallholders allocatively efficient? Evidence from Irish potato producers in Nyandarua North district

Gideon A. Obare[1,2]*, Daniel O. Nyagaka[3] Wilson Nguyo[1] and Samuel M. Mwakubo[4]

[1]Department of Agricultural Economics and Business Management, Egerton University, Kenya.
[2]Food Security Center, University of Hohenheim, Germany.
[3]Research Extension Liaison Division, Ministry of Agriculture, Kenya.
[4]Department of Economics and Agricultural Resource Management, Moi University, Kenya.

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Irish potato production in Kenya has been on the decline, yet this crop is a major staple and a source of cash from sales. Using a random sample of 127 smallholder farmers in Nyandarua North district this paper applied a dual stochastic efficiency decomposition technique and a two - limit Tobit model, after disaggregating economic efficiency components using a dual stochastic frontier function, to analyze resource allocative efficiency in Irish potato production. This is in view of the unclear determinants of declining potato production trends in Kenya and considering that the Irish potato is a major staple and cash crop. The paper establishes that Irish potato production in Nyandarua North district is characterized by decreasing returns to scale with a mean allocative efficiency of 0.57. It was further established that farming experience, access to extension and credit, and membership in a farmers' association positively and significantly influenced allocative efficiency. Implications of the study results are drawn.

Key words: Efficiency, productivity, stochastic frontier functions, Irish potato, Kenya.

INTRODUCTION

Irish potato is the second most important food crop in Kenya after maize (Ministry of Agriculture, 2007). The crop is one of the most important sources of income and employment in the rural areas (Olanya et al., 2006). The annual potato acreage in Kenya is about 100,000 hectares annually, which is distributed among approximately 500,000 smallholder farmers. The average annual production is about 1 million tones with an average yield of 7.3 metric tons per hectare (mt/ha). The Irish potato farmers own, on average, 2 hectares of land. Thus, increased productivity is the only viable option to enhance production (Ogola et al., 2002), given that production increase through land expansion is limited.

Various government supported research and development activities have been undertaken in an effort to improve smallholder resource productivity. For example, efforts towards development of the Irish potato industry in Kenya have focused on the development and dissemination of high yielding varieties (Ministry of Agriculture, 2007). Over the years and despite the efforts directed at improving Irish potato production, low resource productivity still remains a major challenge in the subsector - the average national farm level yields of 7.3 mt/ha compares unfavorably with a potential of 14.5 - 20 mt/ha under farm level conditions and those from research stations of 25 - 35 mt/ha (Kenya Agricultural Research Institute [KARI], 2005). This suggests that the array of technological advances generated through research have not yet translated into increased efficiency and resource productivity.

*Corresponding author. E-mail: ga.obare@yahoo.com. Tel: +254 51 2217781 Ext 3184.

Of particular interest to the sector is the fact that the consumption of Irish potatoes and its associated products is growing particularly among urban consumers. Whereas identifying and understanding the determinants of allocative efficiency is useful in designing appropriate policy measures to enable Irish potato producers to increase productivity, and subsequently enhance food security and poverty allocation, through improved efficiency, we are not aware of any study on allocative efficiency of potato producers in Kenya. The aim of this paper is to establish the current levels of allocative efficiency and the attendant influence factors, of smallholder Irish potato producers in Nyandarua North district of Kenya.

MATERIALS AND METHODS

The study area

The study was conducted in Nyandarua North district in Central Province of Kenya situated in the central part of the country. The district was selected because it is one of the major Irish potato growing districts of Kenya. Of the approximately 100 000 ha of land under Irish potato cultivation in Kenya, 17 500 ha (17.5%) are located in Nyandarua North district[1]. The district falls within the central highlands with an altitude range of between 2,350 and 3,000 m above sea level with a mean temperature of 22°C. The mean annual rainfall is 1,000 mm and reliable.

Land ownership is predominantly freehold. The majority of the farms in the area are small scale. The land size per household varies across the divisions but with an average of 2 hectares (Jaetzold 2006). Agriculture is the main economic activity in the district with dairy production being dominant, and followed by Irish potato production. The district has two planting seasons: the long and short rain. Irish potato is planted in both seasons of the year. The major cash crops in the district include wheat, pyrethrum and horticultural crops such as cabbages, garden peas and carrots.

Data

A survey of the production practices and household characteristics of smallholder Irish potato producers was conducted in June 2008. Data for the study relate to 127 Irish potato producers surveyed during the second production season of October to December for the year 2007/2008. Although Irish potato is grown in two seasons (as already indicated), data were drawn from a single production season. This was intended to minimize the effect of seasonal variation on input use and yield. A two stage sampling technique was used to collect primary data. First, two sub - locations were randomly selected from each of the locations. Thereafter a random sample of 127 households from 31 sub - locations was selected for the survey. Data were collected with the use of a structured questionnaire on output levels, input use in Irish potato production, as well as socioeconomic characteristics. Data on land area under Irish potato cultivation (hectares), family and hired labour (man - days), quantity of fertilizer (kg), quantity of seed (kg), and quantity of pesticides (grams) were collected. The labour input variable was elicited as the number of man - days used in potato production, with a unit man - day being equivalent to 8 h of work performed by an average worker.

Additional data were collected on household's socio economic characteristics and institutional factors including: age, gender, formal education and farming experience of household head; household access to extension and credit; and membership in farmers' associations, as well as the average district wide input and output prices.

The age variable was used to test the hypothesis that younger farmers are more likely to adopt new innovations than older ones, which then would be reflected in higher allocative efficiency. Older farmers are less likely to have frequent contacts with extension workers and less inclined to adopt new techniques and modern inputs, whereas younger farmers with greater opportunities for formal education, may be more skillful in the search for information and the application of new techniques (Nchare, 2007). The formal education variable, measured by the number of years of formal education, captures human capital of the household head and is postulated to have a positive impact on efficiency. The number of years of farming experience variable is likely to be a potential source of allocative efficiency gains through learning by doing. The access to extension variable was measured by using the number of visits to the farm by extension workers. It was included to capture the effects of farmers' contact with extension services on allocative efficiency.

Analytical strategy

Following Bravo - Ureta and Pinheiro (1997) we used parametric stochastic efficiency decomposition approach to measure allocative efficiency in Irish potato production. This approach is an extension of Kopp and Diewert (1982) efficiency estimation procedure. Its advantage lies in the application of a stochastic frontier model with a disturbance term specification that captures noise, measurement error and exogenous shocks beyond the production unit. The stochastic frontier production function model is given as:

$$Y_i = f(X_i;\beta) + \varepsilon_i \tag{1}$$

Where; Y_i measures the quantity of output; X_i is a vector of the input quantities; β is a vector of parameters to be estimated; $f(X_i;\beta)$ is a frontier production function; and ε_i is a composite error term (Aigner et al. 1977). Following Aigner et al. (1977) the composite error term is determined as:

$$\varepsilon_i = \nu_i + \mu_i \tag{2}$$

Where; ν_i is assumed to be an independently and identically distributed that is iid (with $\nu \sim N(0,\sigma_\nu^2)$) random error which represents random variability in production that cannot be influenced by producers, μ_i is a non negative random variable associated with technical inefficiency in production and is iid as half normal, $\mu_i \sim N(0,\sigma_\mu^2)$. Given this framework, the frontier production function $f(X_i;\beta)$ then measures the maximum potential output for a given input vector, X_i. Within this context, both ν_i and μ_i cause actual production to deviate from the frontier.

[1] Nyandarua North district was hived-off from what was formerly the larger Nyandarua district

Using a Cobb Douglas functional specification to model Irish potato production technology, the frontier production function in equation (1) was estimated using maximum likelihood estimation procedures which provides estimators for β and variance parameters, $\sigma^2 = \sigma_v^2 + \sigma_\mu^2$ and $\gamma = \sigma_\mu^2/\sigma^2$. To empirically measure efficiency, deviations from the frontier are separated into a random (ν) and an inefficiency (μ) component. Following Jondrow et al. (1982) and given the distribution and independence assumptions on ν_i and μ_i, in addition to the fitted values of ε_i the conditional mean of μ_i was estimated as:

$$E(\mu_i \mid \varepsilon_i) = \sigma_* \left[\frac{f^*(\lambda\varepsilon_i/\sigma)}{1 - F^*(\lambda\varepsilon_i/\sigma)} - \frac{\lambda\varepsilon_i}{\sigma} \right] \quad (3)$$

Where; f^* is the standard normal density function and F^* is the distribution function and with, both functions being evaluated at $\lambda\varepsilon_i/\sigma$, and $\sigma_* = \sigma_v \sigma_\mu / \sigma$, where σ_v and σ_μ represent the standard errors of the systemic (v) and one sided (μ) parameters, respectively. From these calculations, the estimates of v and μ are then elicited.

According to Bravo-Ureta and Pinheiro (1997) the *i*th firm's efficiency is measured using its adjusted output. The adjusted output is derived by subtracting the random error ν_i from both sides of equation (1) thus:

$$Y_i^* = f(X_i;\beta) - \mu_i = Y_i - \nu_i \quad (4)$$

Where; Y_i^* is the adjusted output of the *i*th firm and μ_i is obtained from equation (3). Adjusted output Y_i^* is then used to derive the *i*th firm technically efficient input vector X_{it} by simultaneously solving equation (4) and the observed input ratios $X_1/X_i = k_i$ ($\forall$ i > 1), where k_i is equal to the observed ratio of, for example two inputs used in the production of Y_i^*. Given the assumptions of Cobb Douglas technology the frontier production function is self - dual (Xu and Jeffrey, 1997). The dual cost frontier can be derived analytically from the production function in equation (1) as follows:

$$C_i = h(P_i, Y_i^*; \Phi), \quad (5)$$

Where; C_i is the minimum cost of the *i*th firm associated with output Y_i^*; P_i is a vector of input prices for the *i*th firm; and Φ is a vector of parameters to be estimated. The economically efficient input vector for *i*th firm, X_{ie}, is obtained by applying Shephard's Lemma (Shephard, 1970) and incorporating the firm's input price and adjusted output level into the derived system of input demand equations as given by:

$$\partial C/\partial P_i = X_{ie}(P_i, Y_i; \Phi) \quad (6)$$

Where; Φ is a vector of estimated parameters. The observed, technically efficient and economically efficient costs of production of the *i*th firm are equal to $\Sigma X_i P_i$, $\Sigma X_{it} P_i$, and $\Sigma X_{ie} P_i$ respectively. These cost measures are used to compute the allocative (AE) efficiency index for *i*th firm as follows

$$AE_i = \sum X_{ie} P_i / \sum X_{it} P_i \quad (7)$$

To determine the relationship between socioeconomic and institutional factors and the computed indices of allocative efficiency a two - limit Tobit procedure was used. The Tobit model was adopted because the allocative efficiency indices lie within a double bounded range of 0 to 1 that is censored in both tails. This means that any application of the least squares method for parameter estimation would lead to biased estimates (Hossain, 1988).

RESULTS AND DISCUSSION

Table 1 presents the basic characteristics of sample farms. The Irish potato acreage was small at a mean of 0.34 ha. The average age and the farming experience of the household head were 47 and 14 years, respectively, and a mean of 9 years of formal education. The sample Irish potato farms averaged 2.44 ha with a standard deviation of 3.03 hectares. The average yields were 10.73 t/ha with a variation of between 6.83 and 20.35 t/ha, suggesting considerable room for improving Irish potato yields. On average 150.5 man days/ha of labor, 1592.10 kgs/ha of seed, and 238.12 kg/ha of fertilizer are used by farmers. Only 35% of the total sample of farmers had access to credit while 42% belonged to a farmers' association. Households received an average of one extension visit per year.

The maximum likelihood parameter estimates of the stochastic production function were obtained using FRONTIER 4.1 (Coelli, 1996) and the results are presented in Table 2. The model variance (γ) is significantly different from zero at 1% level. This implies that the inefficiency effects are significant in determining the level and variability of outputs of Irish potato producers in the study area, and that applying the traditional average (OLS) production function with no technical inefficiency, effects would not have been a robust representation of the data generation process. The estimated value of γ is 0.85, which means that 85% of the variation in farm output was due to technical inefficiency. The results show the expected signs of the coefficients of the stochastic production frontier and all the parameter estimates were statistically significant. The following elasticities were obtained from the estimated model: plot size 0.373 (t = 2.93), labour 0.205 (t = 2.156), seed 0.175 (t = 1.96), fertilizer 0.071 (t = 3.23) and agrochemicals 0.031 (t = 3.10). The sum of the output elasticities is 0.855 implying that the producers were experiencing decreasing returns

Table 1. Descriptive statistics for Irish potato producers.

Variable	Unit	Mean	Std. Dev	Min.	Max.
Potato yield	tones/ha	10.73	4.31	6.83	20.35
Plot size	Hectares	0.34	0.21	0.08	1.21
Labour	Man-days/ha	154.19	53.90	95.08	345.45
Seed	Kilograms/ha	1592.10	639.22	1326.67	2975.38
Fertilizer	Kilograms/ha	238.12	145.34	0	653.33
Pesticides	Grams/ha	1377.86	1441.93	0	4900
Age of household head	Years	47.06	10.643	26	70
Level of education	Years	9.59	3.003	0	18
Farming experience	Years	14.13	8.232	2	35
Extension visit	Number of visits	1.09	1.362	0	6
Farm size (acres)	Hectares	2.44	3.03	0.10	24.28

Characteristics of hh* head	Frequency	Percent
Gender of hh head		
Male	89	70
Female	38	30
Access to credit		
Yes	44	35
No	83	65
Belongs to farmer association		
Yes	53	42
No	74	58

*hh means household head Source: Field survey data (2008).

Table 2. OLS and maximum likelihood estimates for Irish potato producers (Nyandarua North district, 2008).

Variables	OLS	MLE
Intercept	0.639(0.747)	1.506**(0.617)
Ln(Plot size)	0.260(0.146)	0.373***(0.127)
Ln(Labour)	0.241**(0.103)	0.205**(0.095)
Ln(Seed)	0.216**(0.113)	0.175**(0.089)
Ln(Fertilizer)	0.082***(0.024)	0.071***(0.022)
Ln(Pesticides)	0.033***(0.018)	0.031***(0.010)
Function coefficient	0.832	0.855
F statistic model	55.80	
F statistic CRTS	7.287	
σ_μ		0.491
σ_v		0.203
σ^2		0.282
γ		0.854***(0.074)
Log likelihood	-50.32	-46.76
Adj. R^2	0.70	

Note: Values in parentheses represent standard errors. CRTS means constant returns to scale. *, **, *** significant at the 10, 5, and 1% probability levels, respectively.

to scale. The restricted least squares regression was formally used to test the null hypothesis that the production frontier exhibits the property of constant returns to scale. The calculated F statistic was 7.287, which exceeded the critical value of 3.919 at the 1% level of significance. Based on the results of the Restricted Least Squares regression, the null hypothesis was rejected ($P < 0.01$). This means that the production process was not subject to constant returns to scale - which in a way validates the decreasing returns process from the earlier mentioned model results. Plot size has the largest elasticity followed by labour. This suggests that productivity would be higher if more land is brought under Irish potato production, again implying that land would be the most limiting factor of production and possibly the primary reason why farmers are experiencing decreasing returns to scale. In addition, technologies that enhance the productivity of land and labour would achieve significant positive effects on Irish potato production in the study area. The frequency distribution of the estimated allocative efficiency indices for the sample Irish potato farms are presented in Table 3. The predicted allocative efficiency indices varied from 0.41 to 0.86 with a mean of 0.57. This result suggests that there were significant allocative inefficiencies in Irish potato production in the study area. This implies that by improving the allocative efficiency of Irish potato, farmers can reduce their costs by about 43% of the technically efficient cost of production without reducing output. The estimated mean allocative efficiency of 0.57 suggests that were an average farmer in the sample to achieve the allocative efficiency (AE) level of its most efficient counterpart, then the average farmer could realize a 33 per cent cost savings (that is $1-[57.3/85.5 \times 100]$). The frequency distribution of the farm specific allocative efficiency indices showed that none of the sample farms obtained an allocative efficiency index below 0.40 while 42% of farms had an allocative efficiency level of more than 0.60.

The parameters of the two - limit Tobit model are presented in Table 4. The estimated results reveal that experience of the household head, access to extension, access to credit, and membership in a farmers' organization each had a positive impact on allocative efficiency. However, this study found no significant relationship between education and allocative efficiency. Hence, it can be inferred that allocative efficiency is neutral to the household head's level of education. Years of experience of the household head showed a positive and significant influence on allocative efficiency. The coefficient of farmers' experience is significant at 10% level. This result corroborates those found by Amara et al. (1999) in a Canadian and Khai et al. (2007) in a Vietnam study. The positive influence implies that allocative efficiency increases with the number of years spent by the household head in Irish potato production which suggests that Irish potato farming in the study area is highly dependent on the experience of farmers. Experience in Irish potato production may lead to better managerial skills being acquired over time (Bozoglu and Ceyhan, 2007). Thus more experienced farmers with Irish potato production technologies in general were more likely to apply inputs in an optimal manner. Amara et al. (1999) argue that increased farming experience may lead to better assessment of the importance and complexities of good farming decision making including the efficient use of inputs. The results revealed that regular visits by extension workers influenced farmers' allocative efficiency at 5% level of significance. Similar results were reported by Bozoglu and Ceyhan (2007) and Binam et al. (2004) in Turkey and Cameroon, respectively. The positive and significant estimated coefficient for contact with extension workers could be attributed mainly to the fact that knowledge gained from these contacts could have influenced Irish potato producers to adopt new technologies to improve the efficiency. This result is in line with Nchare (2007) who found that regular contact with extension workers facilitates practical use of modern techniques and adoption of improved agronomic production practices. Extension services on crop price patterns, seed varieties, crop management and marketing increase farmers' ability to optimize the use of resources. The results further indicate that access to credit has a positive and statistically significant effect on allocative efficiency at 1% level, which suggests that, on average, farmers with access to credit tend to exhibit higher levels of efficiency. This finding is consistent with the results by Binam et al. (2004) and Abdulai and Eberlin (2001) for farmers in Cameroon and Nicaragua, respectively.

Access to credit permits a farmer to enhance efficiency by overcoming liquidity constraints which may affect their ability to apply inputs and implement farm management decisions on time. Use of credit therefore loosens financial constraints, ensures timely acquisition and use of inputs and results in increased allocative efficiency. Borrowers may be, in comparison to their counterparts, more motivated to allocate efficiently to realize maximum returns in order to repay the credit. The positive and highly significant relationship between membership in a farmers' association and allocative efficiency suggest that farmers who are affiliated to farmers' organizations experience higher allocative efficiency. This finding is similar to the finding by Binam et al. (2004) for farmers in Cameroon. Most smallholder producers form groups to pool resources as way to mitigate the consequences market imperfections. This significant relationship between membership in a farmers' organization and allocative efficiency may be attributed to the fact that farmers who belong to an organization are likely to benefit

Table 3. Frequency distribution of allocative efficiency indices.

Efficiency (%)	No.	%
>85	0	0
>80≤85	1	1
>75≤ 80	0	0
>70 ≤ 75	0	0
>65 ≤ 70	2	2
>60 ≤ 65	7	6
>55 ≤ 60	42	33
>50 ≤ 55	29	23
>45 ≤ 50	23	18
>40 ≤ 45	20	16
>35 ≤ 40	3	2
>30 ≤ 35	0	0
>25 ≤ 30	0	0
>20 ≤ 25	0	0
>15 ≤ 20	0	0
>10 ≤ 15	0	0
>10	0	0
Sample size	127	
Mean (%)	57.3	
Minimum (%)	40.6	
Maximum (%)	85.5	

Table 4. Two-limit Tobit model estimates for determinants of allocative efficiency (dependent variable = allocative efficiency indices).

Variable	Coefficient	Std. Dev.	t - value
Constant	3.789***	0.151	25.05
Gender of household head	0.002	0.020	0.09
Age of producer	0.028	0.041	0.70
Education level of producer	0.001	0.028	0.03
Experience of producer	0.029 *	0.016	1.80
Contact with extension agents	0.019**	0.008	2.39
Access to credit	0.046**	0.023	2.11
Membership in a farmers' association	0.092***	0.024	3.86
Log likelihood	116.78		

*,**, *** significant at the 10%, 5%, and 1% level, respectively.
Source: Survey data, 2008.

from better access to inputs and to information on improved production practices. In addition, if there are many adopters of a new technology in similar conditions as is often the case with an innovation in agriculture, then the process of learning about the technology may be more social -network driven. New users of the technology may learn from each other, thereby generating significant technology spillovers. However, with respect to age, gender and household head's level of education, this study found no statistically significant relationship.

CONCLUSION AND IMPLICATIONS

In this paper, the allocative efficiency levels for a sample of Irish potato farmers in Nyandarua North district, Kenya has been examined using a stochastic parametric efficiency decomposition technique. The parametric approach is based on Kopp and Diewert (1982) cost decomposition approach where a Cobb Douglas stochastic production frontier was estimated and the corresponding dual cost frontier derived analytically. Socioeconomic and institutional factors influencing the differences in observed levels of allocative efficiency were also determined. The results indicate a significant variation in allocative efficiency ranging from 0.40 to 0.86 with a mean of, 0.57, which implies considerable allocative inefficiency exists in Irish potato production in the study area. Nevertheless, these results show that there is a substantial potential for enhancing profitability by reducing costs through improved efficiency. By operating at full allocative efficiency levels, on average, the sample producers would be able to reduce their costs by about 43% of the technically efficient cost of production. If the sample potato producers were fully allocatively efficient in production, the potential cost saving will enhance profitability of the Irish potato producers, improve income, with a resultant impact on poverty reduction.

The maximum likelihood estimation of the Cobb Douglas stochastic frontier model shows that the estimated values of the variance parameters were significant which indicates that technical inefficiency has an impact on output. This suggests that a conventional production function was not an adequate representation of the data. The estimation results revealed that all the inputs were significant in the Irish potato production function. Land area planted to Irish potato (plot size) and labour showed the greatest elasticity, meaning that these two inputs have a major influence on Irish potato production. The findings further show that farming experience, number of extension visits, access to credit and membership in a farmers' association variables positively and significantly influence farmers' allocative efficiency. However, and contrary to expectation educational level of the household head was not found to significantly influence allocative efficiency. These findings have important policy implications in promoting efficiency of Irish potato farmers in the study area and Kenya in general.

From a policy standpoint, the positive effect of access to extension services implies that enhancing smallholder farmers' access to information and new technologies will improve the level of efficiency. A possible implication that can be drawn from this study is that, policy makers need to focus on establishing innovative institutional arrangements that enhance extension and farmer training. Use of group approach, farmer - led extension e.g. farmer field schools, and strengthening mass media to supplement and complement extension workers' efforts besides extensive use of information and communications technology (ICT) to support agricultural extension would be entry points for assessment. Those found effective should be promoted. General improvement of rural access roads will also enhance access to extension services (Muyanga and Jayne, 2006). The relationship between allocative efficiency and access to credit established in this study suggests that improving smallholder potato farmers' access to credit will enhance efficiency. These finding imply that institutional arrangements that aim at reducing transaction costs of providing farmers greater access to credit would have the potential of increasing efficiency. From the findings of this study, it is apparent that policy makers need to: (i) introduce appropriate legislation that encourage commercial and microfinance institutions to accommodate small agricultural producers; (ii) provide incentives to financial institutions to extend loans to smallholder farmers, such as income tax exemptions on interest incomes and tax credits; (iii) support mobilization of financial resources through savings and credit organization (SACCOs) and other community based lending systems.

The results on the influence of membership in a farmers' association on allocative efficiency suggest that policy makers need to foster the formation and development of farmers' association, and improve efforts by government and nongovernmental organizations on building the capacity of farmers in community mobilization and management skills. The policy challenge, therefore, is to devise innovative and cost effective measures to encourage household membership into farmers groups. Since collective action is effective with smaller groups, it is worthy to increase the number of groups (Mwakubo et al., 2006). Therefore, there is need among governmental and nongovernmental organizations to recognize the importance of formation of viable farmer groups such as common interest groups (CIGs) so that support can be channeled to these farmer groups to enhance efficiency. Overall, this study concludes that substantial produc-tivity gains can be obtained by improving the allocative efficiency of Irish potato producers. To achieve this, the government and other stakeholders in the Irish potato sector should attempt to create a favourable institutional environment that would facilitate the farmers' access to extension to formal credit. This can be achieved through mobilizing farmers into farmer organizations through which collection action can be used to collaterize risks in addition to the organization being an avenue for information flow and exchange.

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