Economic Efficiency of Smallholder Irish Potato Producers in Kenya: A Case of Nyandarua North District

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Abstract

With declining Irish potato production trends in Kenya this paper identifies and analyses factors that influence the economic efficiency of smallholder Irish potato producers in Kenya by drawing on data from random sample of 127 smallholder farmers from Nyandarua North district. A dual stochastic parametric decomposition technique is used to disaggregate economic efficiency components and a two-limit Tobit model is used to derive efficiency indices as a function of a vector of socio-economic characteristics and institutional factors. Empirical results show decreasing returns to scale in production. The mean economic efficiency is 0.39 with a range of 0.12 - 0.66. Education, access to extension, access to credit and membership in a farmers association positively and significantly influence economic efficiency. Innovative institutional arrangements that enhance extension and farmer training, accompanied with improved access to credit is likely to enhance potato production efficiency.

Key words: Efficiency, productivity, stochastic frontier functions, Kenya

JEL Classification: D12, D24, O33, Q16

Introduction

Irish potato is the second most important food crop in Kenya after maize (MOA, 2007). The crop plays a significant role in the Kenyan economy. Approximately 500,000 smallholder farmers produce about 1 million tones from 100,000 ha of cultivated land area and Kenya's production constitutes 0.3% of the world's total production and 6.5% of Africa's production (MOA, 2006). Improving productivity in the Irish potato sub-sector and reducing poverty is a major policy objective of the Kenyan government.

Various government supported research and development activities have been undertaken in an effort to raise productivity of smallholder farmers. Efforts towards development of the Irish potato industry in Kenya have focused on development and dissemination of high yielding varieties (MOA, 2006). Despite the efforts directed at improving Irish potato production over the years, low productivity remains a major challenge in the sub-sector - the average national farm level yields of 7.3 metric tonnes per hectare (mt/ha) compares unfavorably with on research station yields of 25 – 35 mt/ha and a potential of 14.5-20 mt/ha under farm level conditions (KARI, 2005). This means technological advances generated through research have not translated to increased efficiency and resource productive capacity.

We aim to establish the current levels of economic efficiency of smallholder Irish potato producers in Nyandarua North district in Kenya and to identify factors influencing levels of farm production and economic efficiency. In so doing we hope to provide insights to constraints to improved Irish potato production and provide avenues for possible policy intervention towards improved potato production in Kenya.

The remainder of this paper is organized as follows: In section two a description of the study area and data is presented, followed by a discussion of the analytical framework used in the study in section three. In section four, the results of the analysis are then presented and discussed. Section five summarizes the study findings and policy implications.

1. The study area

The study area covers Nyandarua North district in Central province of Kenya situated in the central part of the country. The district 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, 17500 ha (17.5%) are located in Nyandarua North district (MOA, 2007). The district falls within the Central highlands with an altitude range of between 2350 m and 3000 m above sea level.

There are two major agro-climatic zones in the district: Upper Highland UH2 and UH3. The mean annual rainfall is 1000 mm. The district is characterized, by reliable rainfall. The rainfall is bimodal and can reach 130mm/month in the months of July and August. Mean maximum temperature is 22^{o}C and the mean minimum temperature ranges between 10 to 16^{o}C. The climate is conducive to rich and varied agricultural production (Jaetzold et al., 2006). The population of Nyandarua North district is about 249,280 persons (1999 census) with about 122,584 male and 126,696 female. The population is 90% rural based consisting of 55,228 households with a mean household size of 4 persons (Jaetzold et al., 2006).

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 on average it is 5 acres (Jaetzold et al., 2006). Agriculture is the main activity in the district with Dairy production as

the dominant farming activity followed by Irish potato production. The district has two planting seasons: the long and short rain seasons. 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.

2. Data

A two stage sampling technique was adopted to enable for the establishment of a sample frame. In the first stage two sub-locations were selected from each of the locations on a random basis. Thereafter a random sample of 130 households from 31 sub-locations was selected for the survey. Data were collected with the use of a structured questionnaire on output levels and input use in Irish potato production, as well as socio-economic characteristics. Additional data on five productive inputs namely: land area under Irish potato cultivation (acres), family and hired labor (man-days), quantity of fertilizer (kg), quantity of seed (kg), and quantity of pesticides (grams) were collected. Labor was measured in man-days with 1 man-day being equal to 8 hours of labor. Further average district-wide input and output prices for input and output was collected as well.

3. Analytical framework

Following Bravo-Ureta and Pinheiro (1997) we use a parametric stochastic efficiency decomposition approach to measure the economic efficiency in Irish potato production. This is an extension of Kopp and Diewert (1982) economic efficiency estimation procedure. The advantage of this approach is 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 specified as follows:

$$Y_i = f(X_i;\beta) + \varepsilon_i \quad (1)$$

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 at al., 1977). Following Aigner et al., (1977) the composite error term is given as:

$$\varepsilon_i = \nu_i - \mu_i \quad (2)$$

where ν_i is assumed to be independently and identically distributed as $\nu \sim N(0,\sigma_\nu^2)$ random error and 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 identically and independently distributed (iid) as half-normal, $\mu_i \sim N(0,\sigma_\mu^2)$. The frontier production function $f(X_i;\beta)$ measures the maximum potential output for a given input vector, X_i. Both ν_i and μ_i cause actual production to deviate from the frontier.

Using a Cobb-Douglas functional specification to model Irish potato production technology, the frontier production function in equation (1) is estimated using maximum likelihood estimation procedures which provides estimators for β and variance parameters, $\sigma^2 = \sigma_\nu^2 + \sigma_\mu^2$ 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 can be estimated as:

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

where $\sigma_*^2 = \sigma_\mu^2\sigma_v^2/\sigma^2$, f^* is the standard normal density function and F^* is the distribution function both functions being evaluated at $\lambda\varepsilon/\sigma$. From this calculation, estimates of ν and μ may be determined.

According to Bravo-Ureta et al., (1997) the *i*th firm efficiency is measured using adjusted output. This output is derived by subtracting the random error ν_i from both sides of equation (1) thus:

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

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 the two inputs in the production of Y_i^*. Given the assumption of Cobb-Douglas technology the frontier production function is self-dual (Xu et al., 1998). The dual cost frontier can be derived analytically from the production function in equation (1) thus:

$$C_i = h(P_i, Y_i^*;\Phi), \tag{5}$$

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 derived by applying Shephard's Lemma (Shephard, 1970) and substituting the firm's input price and adjusted output levels into the derived system of input demand equations given by

$$\partial C_i/\partial P_k = X_{ie}(P, Y^*;\Phi), \tag{6}$$

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

$$EE_i = \sum X_{ie} P_i / \sum X_i P_i \quad (7)$$

To determine the relationship between socio-economic and institutional factors and the computed indices of economic efficiency we use a two-limit Tobit procedure. The Tobit model was adopted because the economic efficiency scores lie within the range of 0 to 1.

4. Results and discussion

The mean yield is 39.2 bags/acre while the yields vary between a low of 32.15 and a high 44.16 bags/acre on average (Table 1), suggesting considerable room for improving Irish potato yields. The mean farm size is 6.03 acres with 7.49 acres standard deviation. On average 61 man-days/acre of labor, 783 kg/acre of seed, and 85.23 kg/acre of fertilizer are used by farmers. The average household head's farming experience was 14 with a mean of 9 years of formal education. The average age of the sample farmers was 47 years. Only 35% of the farmers had access to credit while 42% belong to a farmers' association. Households received an average of one extension visit per year.

The maximum likelihood parameter estimates of the stochastic production were obtained using FRONTIER 4.1 (Coelli, 1996) and the results are presented in Table 2. The variance of the technical inefficiency parameter γ is 0.85 and is significantly different from zero. This implies that the inefficiency effects are significant in determining the level and variability of output 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. A null hypothesis that production frontier exhibits the property of constant returns to scale, using a Restricted Least Squares regression is rejected ($P < 0.01$).

Table 1: Descriptive statistics for Irish potato producers

Variable	Unit	Mean	Std. Dev
Output	Bags	32.51	22.402
Yield	Bags/acre[1]	39.29	15.39
Plot size	Acres	0.83	0.526
Labour	Man-days	50.56	32.112
Seed	Kilograms	650.36	496.527
Fertilizer	Kilograms	85.24	72.373
Pesticides	Grams	483.38	554.763
Gender of household head	1 = male, 1 = female	0.70	0.459
Age of household head	Years	47.06	10.643
Level of education	Years	9.59	3.003
Experience of producer	Years	14.13	8.232
Extension visit	No. of visits	1.09	1.362
Access to credit	1=yes, 0=no	0.35	0.501
Farmer association	1=yes, 0=no	0.42	0.416
Family size	Persons	4.82	1.706
Farm size (acres)	Acres	6.03	7.489

[1]1 acre=0.405ha

Source: Field survey data, 2008.

Table 2: OLS and Maximum likelihood estimates for Irish potato producers, Nyandarua North district, 2008 (Dependent variable = Yield)

Variables	OLS	MLE
Intercept	0.639(0.747)	1.506**(0.616)
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***(0.011)	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***(0.055)
γ		0.854***(0.074)
Log-likelihood	-50.32	-46.75
Adj. R^2	0.70	

Note: Values in parentheses represent standard errors. CRTS means Constant Returns to Size.

*, **, *** significant at the 10%, 5%, and 1% level, respectively

All the parameter estimates are statistically significant in the frontier model. The following elasticities were obtained: plot size 0.373 (t = 2.93), labour 0.205 (t = 2.156), seed 0.175 (t = 1.96), fertilizer 0.071 (t = 3.13) and agrochemicals 0.031 (t = 3.01). The sum of the output elasticities is 0.855 implying decreasing returns to scale. Plot size has the largest elasticity followed by labour. Agrochemicals recorded the lowest elasticity. This suggests that productivity would be higher if more land is brought under Irish potato production.

Table 3: Frequency Distribution of Economic Efficiency

Efficiency (%)	No.	%
>85	0	0
>80≤85	0	0
>75≤ 80	0	0
>70 ≤ 75	0	0
>65 ≤ 70	1	1
>60 ≤ 65	2	2
>55 ≤ 60	1	1
>50 ≤ 55	9	7
>45 ≤ 50	17	13
>40 ≤ 45	26	20
>35 ≤ 40	27	21
>30 ≤ 35	17	13
>25 ≤ 30	12	9
>20 ≤ 25	9	7
>15 ≤ 20	4	3
>10 ≤ 15	2	2
>10	0	0
Sample	127	
Mean (%)	39.1	
Minimum (%)	12.3	
Maximum (%)	66.1	

The frequency distribution of the estimated economic efficiency indices for the sample Irish potato farms are presented in Table 3. The predicted economic efficiencies range from a minimum of 12.3% to a maximum 66.1%. The estimated mean economic efficiency is 39.1% suggesting that were an average farmer in the sample to achieve the economic efficiency (EE) level of its most efficient counterpart, then the average farmer could realize a 42.4 per cent cost savings (i.e., 1-[(39.1/66.1x100)]).

The parameters of the two-limit Tobit model are presented in Table 4. The results reveal that the level of education, experience of the household head, access to extension, and access to credit each has a positive impact on economic efficiency. Membership in a farmers' organization has a negative and significant relationship with economic efficiency. The positive and highly significant coefficient of education at 1% level indicates that farmers with higher levels of education tend to be more efficient in production. Better performance by more educated farmers may be attributed to the fact that education gives the farmers the ability to perceive, interpret and respond to new information and improved technology such as fertilizers, pesticides and planting materials much faster than their counterparts. However, Bravo-Ureta et al. (1997) in their study of peasant farmers in Dominican Republic found a negative relationship between education and economic efficiency.

Table 4: Two-limit Tobit model estimates for determinants of economic efficiency (Dependent variable = Economic Efficiency indices)

Variable	Coefficient	Std. Dev.	*t*-value
Constant	3.094***	0.318	9.72
Gender of the household head	0.071	0.044	1.62
Age of the household head	-0.071	0.086	-0.83
Level of education	0.162***	0.058	2.79
Experience	0.086**	0.034	2.51
Access to extension	0.064***	0.017	3.74
Access to credit	0.212***	0.046	4.59
Membership in association	-0.101**	0.050	-2.01
Log-likelihood	-3.773		

*, **, *** represents significant at the 10%, 5% and 1% level, respectively

The estimated coefficient of the variable representing the producers' experience is positive and significant which indicates that efficiency increases with the number of years spent by the household head in potato production. This suggests that the Irish potato farming in the study area is highly dependent on the experience of farmers which may lead to better managerial skills being acquired over time. This corroborates the findings by Amara et al. (1998) and Khai et al. (2008). Farm households who receive regular extension visits by extension workers appear to be more economically efficient than their counterparts. The coefficient for the access to extension has a highly statistically significant positive relationship with economic efficiency (EE) at 1% level. Similar results were reported by Bozoglu and Ceyhan (2007) and Binam et al. (2004) in Turkey and Cameroon respectively. The positive estimated coefficient for contact with extension workers imply that economic efficiency increases with the number of visits made to the farm household by extension workers. This result is in line with the arguments by Nchare (2007) who indicates that regular contact with extension workers facilitates practical use of modern techniques and adoption of improved agronomic production practices.

The results also indicate that access to credit has a positive and statistically significant effect on economic efficiency levels 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. (2006) and Abdulai et al. (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 hence use of credit therefore loosens financial constraints, ensures timely acquisition and use of inputs and results in increased economic efficiency. It is of crucial importance to provide smallholder farmers who are often cash

constrained with credit in order to facilitate the timely purchase of critical inputs such as inorganic fertilizers and pesticides.

The results indicate a negative and significant relationship between membership in a farmers' association and efficiency contrary to what could be expected. This could be attributed to inadequate efforts by the existing farmers' associations in influencing technology uptake. However, this study found no statistically significant relationship of age and gender each on economic efficiency.

5. Conclusion and policy implications

In this paper the economic efficiency levels for a sample of farmers in Nyandarua North district, Kenya has been examined using a stochastic parametric efficiency decomposition technique. The parametric approach is based on the Kopp and Diewert's (1982) cost decomposition approach where a Cobb-Douglas stochastic production frontier was estimated and the corresponding dual cost frontier derived analytically. Socio-economic and institutional factors influencing the differences in observed levels of economic efficiency were also determined.

The results indicate a significant variation in economic efficiency among sample households. Estimated farm-specific economic efficiency indices ranged from 12.3 to 66.1% with a mean economic efficiency of 39.1% which implies considerable production inefficiency. Nevertheless, this results show that there is a substantial potential for enhancing profitability by reducing costs through improved efficiency. By operating at full economic efficiency levels, on average, the sample producers would be able to reduce their costs by 42.4%. If the sample potato producers were fully efficient in production, the range in potential cost saving

is about Ksh16,954 to Ksh47,130 per acre in production costs annually (two seasons). This translates to an additional daily income of about Ksh47.10 to Ksh130.90 (US$0.60 – 1.30). Given a poverty line of US$1 per day these are significant amounts which indicate that by improving efficiency, the resulting cost reduction will enhance profitability of the potato producers, improved income, with a resultant impact on poverty reduction.

The findings also show that the level of education of the household head, experience, number of extension visits, and access to credit are significant variables for improving the level of economic efficiency. There is therefore a need to expand farmer education complimented by quality and effective extension service on improved agronomic and management practices. An enhanced access to credit will contribute to productivity gains. This means that innovative ways need to be devised that will ensure that farmers are enabled to access credit at a reasonable costs.

The positive impact of education economic efficiency indicates that increase in human capital will enhance the farmer's ability to receive and understand information relating to new agricultural technology. This finding supports argument by Abdulai et al. (2001) that an increase in human capital will augment the productivity of farmers since they will be better able to allocate family-supplied and purchased inputs, select the appropriate quantities of purchased inputs and choose among available techniques. There is therefore a need to promote formal education as a means of enhancing efficiency in production over the long-term period.

The positive estimate for the experience of farmers implies that the number of years in Irish potato farming does lead to better managerial skills being acquired over the years. However,

the coefficient experience was positive but non-significant. This means that the Irish potato farming is not highly dependent on the experience of farmers.

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. Policy makers should focus on innovative institutional arrangements that enhance extension and farmer training such as: (i) use of group approach; (ii) farmer-led extension e.g. farmer field schools; and (iii) strengthening mass media to supplement and complement extension workers efforts besides extensive use of information and communications technology (ICT) to support agricultural extension. Secondly, another area for policy focus is on strategies for integrating women into the training and extension programs, which may also help to increase efficiency in the research area.

The relationship between economic efficiency and access to credit found in this study, suggests that improving farmers' access to formal credit will improve efficiency. Enhancing smallholder Irish potato farmers' access to credit will help improve economic efficiency. To enhance access to appropriate credit packages policy makers should: (i) advocate for appropriate legislation to encourage commercial and microfinance institutions to accommodate small agricultural producers; (ii) support mobilization of financial resources through SACCOs and other community based lending systems; and (iii) support revival and strengthen existing cooperatives.

Overall, this study indicates that substantial productivity gains can be obtained by improving the economic efficiency of Irish potato producers. To meet this objective the Kenyan government and other stakeholders in the Irish potato sector should come up with an

institutional environment that facilitates farmer's accessibility to extension services as well as improved access to formal credit.

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