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Agricultural profitability and technical efficiency: the case of pineapple and potato in SW Uganda

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Abstract

In this study we investigate the profitability of potato and pineapple enterprises and the technical efficiency and drivers of efficiency among potato farmers, chosen purposively within IAR4D project sites in southwestern Uganda. For enterprise profitability, a non-parametric net crop revenue analysis was used, while a stochastic frontier parametric approach was used to analyse technical efficiency. Both potato and pineapple enterprises were found to be profitable, although returns from pineapples were lower. Seasonality impacted on the gross returns of both enterprises. Pineapple prices were lower than for potatoes during the peak seasons, but off-peak prices rose 350% above the peak price, resulting in substantial increases in gross incomes. All potato farms were inefficient. However, female farmers were relatively more efficient than male farmers. Education was positively and significantly associated with efficiency, indicating that public investments in education have complementary and synergistic effects on IAR4D development outcomes in Uganda.

Keywords: technical efficiency; stochastic frontier; profitability; IAR4D

1. Introduction and Motivation for the Study

Agriculture is a key sector in the development of African economies, contributing a significant portion to the national GDP and employing over 75% of the population (Salami *et al*. 2010). However, this agriculture is in the hands of mainly small-scale farmers who use traditional methods and rudimentary tools of production, resulting in unsustainably low crop yields, despite their high commercial and export potential. Among the crops that have increasingly gained importance in Uganda are potato, and horticultural crops including pineapples.

Under the sub-Saharan Africa Challenge Programme (SSACP), farmers of the innovation platforms (IPs) were given an opportunity to select key enterprises for implementation under the IAR4D concept. A total of four IPs were identified in southwestern (SW) Uganda. Potato was selected for the Chahi, Bubare and Bufundi IPs on the basis of food security and income generation, while organic pineapple was selected for Ntungamo on the basis of its market potential. Farmers chose to boost the production and marketing of these enterprises, among others based on the potential that the crops had in the project area. The concern of this research is to ascertain if the farmers' choice of enterprises can be justified empirically.

Given that these farmers are resource-constrained, key questions arise: (i) Are the resources and inputs used in the production of potatoes and pineapples returning the optimum levels of output? (ii) How efficiently can these limited resources be employed to obtain the maximum level of potato output? and (iii) What are the drivers of production efficiency in the districts under study? Assessing the profitability of the enterprises and the efficiency of production is the appropriate way to identify if resources are being put to their best use. Producers need to be aware early enough of the drivers of production efficiency for the enterprises they are involved in.

1.1 Objectives and hypotheses

The major objective of this study was to establish the profitability of farmer-selected enterprises and the technical efficiency of farmers in the IPs of SW Uganda.

The specific objectives were:
(i) To determine the profitability of potato and organic pineapple enterprises;
(ii) To determine the effect of seasonality on profitability;

(iii) To establish the production efficiency of potato-producing farms; and
(iv) To establish the determinants of the efficiency of producers.

The following hypotheses were tested:

(i) $H_0: NFB_{ij} = 0 \; Vs \; H_1: NFB_{ij} \neq 0$ i = potato, pineapple; j = Kabale, Kisoro, Ntungamo. That potato and pineapple enterprises in SW Uganda are not profitable

(ii) $H_0: TE_{Male} = TE_{Female} \; Vs \; H_1: TE_{Male} \neq TE_{Female}$ That there is no significant difference in technical efficiency between female- and male-headed potato farming households.

(iii) $H_0: \beta_{Educ} = 0 \; Vs \; H_1: \beta_{Educ} \neq 0$ That the level of education of household heads is not a significant driver of technical efficiency.

1.2 Justification

The identification of enterprises that lead to the highest returns (rewards) from the farmer's resources is important. When enterprises are profitable, the use of inputs returns more to the farmer than the original investment. Higher profits result in increasing incomes and thereby lead to a sustainable improvement in the livelihoods of the farmers. An enterprise that is not profitable cannot survive in market-oriented production, given the limited resources and the number of competing alternative uses. On the contrary, an enterprise that is highly profitable rewards the farmers with returns on their investments that act as incentives to spur more production. Such enterprises indicate potential for improving the welfare of farmers in the long run.

Farmers are expected to operate rationally, maximising profits while minimising costs. When farmers are not operating efficiently, it implies either that they are employing more units of input to produce the same level of output, or that they produce less output from the same level of inputs as another, more efficient, farmer. It is important to determine if the actual production process follows the economic rationality criterion and, if not, by how much farmers are operating off the efficiency frontier. This information is vital to better guide resource allocation, given the prevailing input and output prices. Outcomes of measures on profitability and efficiency are indicators of farm performance and of farmers' living conditions, and can serve as a basis for future measures of change arising from the implementation of IAR4D project activities. While many authors have studied farm profitability (Ahmad *et al.* 2005; Adil *et al.* 2007a, 2007b) or farm efficiency (Hyuha *et al.* 2007; Tchale 2009; Krasachat 2011) separately, not many studies have combined both performance measures. Unlike most studies, this study uses a parametric approach to determine profitability, and a non-parametric approach to determine efficiency. This is to establish whether or not pineapple and potato farmers are making profit and whether potato farmers are using the production resources optimally. As a result, the study findings will help guide policy by providing policy options to improve farm-level performance of potato and pineapple.

2. Methodology

2.1 Study area, sampling procedure and data types

The study was conducted in the potato IPs of Bufundi in Kabale and Chahi in Kisoro, and in the organic pineapple IP in Ntungamo district in southwestern Uganda. Potato production in Uganda is carried out mainly in the highland areas, at elevations of 1 500 to 3 000 metres above sea level (masl). The highlands of Kabale and Kisoro provide the most favourable environment for potato production and the leading potato producers in Uganda. Kabale district alone produces between 50% and 60% of the total annual potato output consumed in Uganda (Mwang'ombe, 2008). Ntungamo district lies at an average elevation of 1 179 metres. Like Kabale and Kisoro, the major source of livelihood in the district is agricultural crop production. Pineapple growing in the district has traditionally been for home consumption, and two major varieties, the thorny and smooth cayenne types, are grown on approximately 0.5 acres per farmer. In the study area, both potato and pineapples are mainly grown as sole crops.

Data were collected using a pre-piloted questionnaire, which solicited information on household demographics and composition, production outputs, inputs and costs, markets and marketing, access to and use of extension, sources and amounts of credit, as well as production and marketing constraints. The data were coded and entered in a spreadsheet, preceded by data cleaning to ensure data quality. An efficiency analysis was conducted for 108 potato farms in Kabale and Kisoro, and the profitability assessment included additional data from 48 pineapple farms in Ntungamo.

2.2 Empirical approach

2.2.1 Non-parametric

Non-parametric statistics were used in gross margin analysis to provide descriptive evidence of enterprise profitability. Net crop revenue analysis was used to estimate the returns on factors used in the production of potatoes, reflected as returns to variable cost (RVC) and calculated as follows:

$$GFB = OPH * AVP \quad \text{.......} \quad (i)$$

where GFB is gross field benefits, OPH is output harvested, and AVP is the average selling price.

$$NR = GFB - TVC \quad \text{.......} \quad (ii)$$

where NR is net returns, and TVC is total variable cost. Depreciation was not considered for farm equipment, since the same is used in all the enterprises undertaken by the farmer and not exclusively for pineapple or potato. Land is not subject to allowance for depreciation.

$$RVC = {}^{NR}\!/\!_{TVC} \quad \text{.......} \quad (iii)$$

For labour the following equation was used:

$$Rtl = \frac{\frac{1}{n}\sum_{i=1}^{n}(GFB - NLC)}{\frac{1}{n}\sum_{i=1}^{n}(Vflb + Vmlb)} \quad \text{.......} \quad (iv)$$

where NLC is the net cost of labour, and $Vflb$ *and* $Vmlb$ denote total female and male labour respectively. A sensitivity analysis was carried out to establish the range of prices and yields over which net returns remained positive at the farm level. Using the lowest seasonal price (and yield), scenarios were created with five equal percentage point changes below and above the average to determine the variability of net returns across seasons. These scenarios were appropriate, given the wide swings in both output prices and yield that are experienced for agricultural products, and the nature of agricultural production systems, which are largely dependent on nature.

2.2.2 Parametric approach

To obtain the production efficiency of potato farmers, a technical efficiency measure of farm performance was used. Technical efficiency (TE) is a performance measure used extensively in engineering and econometrics, where the decision-making unit (farm or firm) is assessed on the basis of its ability to produce a maximum level of output from a given level of inputs. The computation of this measure can take two approaches: deterministic and stochastic. The stochastic approaches assume a particular distribution of the production function, while the deterministic approaches do not.

The estimation of a stochastic production frontier is based on the assumption that any deviation from the production frontier is attributed to the random component reflecting measurement error, statistical noise and a farm-specific inefficiency component (Ogundele & Okoruwa, 2006). The stochastic production frontier functional form is expressed as:

$$Y_i = f(x_i;\beta)\exp(v_i - u_i) \text{......} (v)$$

where Y_i represents the yield of the *i*th farm, x_i represents the costs of inputs used in the production process, β is a 1 x M vector of coefficients, v_i represents random errors assumed to be distributed IID N$(0,{\sigma_v}^2)$, and u_i represents technical inefficiency assumed to be non-negative of the half normal distribution N$(\mu,{\sigma_u}^2)$. The most common production functions $f(x_i;\beta)$ used include the Cobb-Douglas, the translog and the constant elasticity of substitution (CES) production functions. The procedure predicts a TE score for each farm by estimating the frontier from the following:

$$TE = \frac{Y_i}{Y^*} = \frac{f(x_i;\beta)e^{(v_i-u_i)}}{f(x_i;\beta)e^{v_i}} \text{......} (vi)$$

where Y^* is the frontier output. Farm *i* is only technically efficient (i.e. with an efficiency score of 1) if it operates on the frontier such that $u_i = 0$ and, consequently, $Y_i/Y^* = 1$. If $Y_i/Y^* < 1$ then the farm lies below the frontier and we conclude that the farm is technically inefficient. The estimation procedure followed in this research was based on the Cobb-Douglas production form, largely due to sample size limitations of the data. (A translog stochastic production form that requires interacting variables has a common problem of multicollinearity, requiring the elimination of observations and thereby reducing the sample size.)

2.2.3 The efficiency empirical model

A Cobb Douglas production function was as follows:

$$Y_i = AX_{1ij}^{\beta_{1i}} X_{2ij}^{\beta_{2i}} X_{3ij}^{\beta_{3i}} e^{(V_i - U_i)} \text{......} (vii)$$

$$\ln Y_i = \ln A + \beta_{1j}\sum_{j=1}^{6}\ln X_{1ij} + \beta_{2j}\sum_{j=1}^{3}\ln X_{2ij} + \beta_{3j}\sum_{j=1}^{3}\ln X_{3ij} + V_i - U_i$$

where

Y_i = total potato yield for the *i*th farmer (kg/acre)

X_{1ij} = global macro representing input costs in UShs, including female labour, male labour, agrochemicals, planting material, manure, and postharvest and seed dressing costs

X_{2ij} = potato innovation platforms (Bufundi and Chahi IPs); this is a dummy variable indicating that a potato farmer either belonged to the Bufundi IP of Kabale district or the Chahi IP of Kisoro district

X_{3ij} = potato varieties (Kinigi, Victoria, Rwangume); this is a dummy variable indicating that a potato farmer had three varieties to choose from. The adoption of any one variety implied a 1, and 0 otherwise

V_i = random error term with normal distribution N $(0, \sigma^2)$
U_i = a non-negative random variable, technical inefficiency associated with the farmer
$\beta_0 - \beta_3$ = coefficients associated with each independent macro-variable

The outcome of the above estimation predicts the error term U_i, which represents the inefficiencies associated with each farm. Farmers were categorised by efficiency scores. Three equal classes of efficiency scores were created, representing low, medium and high efficiency classes. Efficiency classes were compared by gender, geographical location, yield, acreage, profitability perceptions, and by knowledge of soil-improving options.

Like probabilities, the predicted distribution of efficiency scores lie within the 0,1 limit. For censored observations we cannot observe the outcome if efficiency scores lie outside those limits. For this situation, ordinary least squares (OLS) give biased estimates, because they do not account for the probability of scores outside the limits. Thus, to obtain the factors influencing production efficiency, the econometric approach was based on a double-censored Tobit model using limited information maximum likelihood (LIML) estimation. The results were compared with those from the OLS and robust regression models to determine the robustness of the estimation. Independent variables postulated to impact on efficiency included the farmer's age in years (Age), level of education (Educ), household size (HHSize), gender (Gen), and the farmer's profit perceptions (knowledge of soil-improving inputs removed) (FPP):

$$u = f(Age, Educ, HHSize, Gen, FPP)$$

3. Empirical Results

3.1 Enterprise cost and yield analysis results

The cost of planting material comprised a disproportionately large component (98.9%) of the total pineapple production costs in Ntungamo. In Kabale and Kisoro, the share of planting material in total costs was 77 and 69.3% respectively. Labour costs comprised the second most important contributor of total production costs in the potato-growing districts (Figure 1).

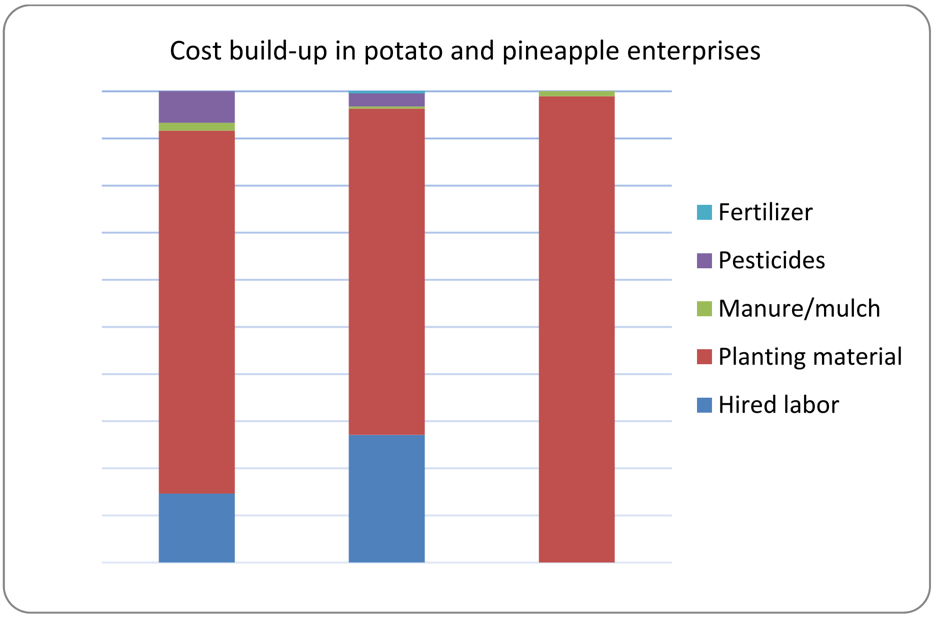

Figure 1: Share of costs in total production

Labour components for potato included charges for primary tillage, planting, mulch/manure application, de-suckering, harvesting and transportation. For pineapple, total variable costs included pre-planting costs, field costs and labour costs for postharvest and marketing operations. In Kisoro the share of fertiliser to potato production costs was 0.3%, while Kabale potato farmers generally did not apply fertilisers, consistent with a national-level survey by CIP in 2005 (Mwang'ombe, 2008) that established that only 7% of Ugandan potato farmers apply inorganic fertilisers on the potato crop. Pesticide use was higher in Kabale than in Kisoro. While the Ntungamo organic pineapple farmers did not apply any agro-chemical inputs, as expected, they spent in excess of 3 000UShs/acre on mulches and manures (Table 1).

Table 1: Enterprise cost analysis

	Av. cost (Shs/acre)		
Input category	**Kabale**	**Kisoro**	**Ntungamo**
Family labour	57,964	49,908	
Hired labour	28,686	65,147	
Total labour	86,650	115,055	84,945
Planting material	151,167	166,830	301,131
Manure/mulch	3,317	1,098	3,265
Pesticides	13,144	6,665	0
Fertiliser	0	1,125	0
Total variable costs	196,314	240,865	304,396

The yield (1 381 kg/acre) obtained by the Kabale farmers was more than by their counterparts in Kisoro, who achieved 1 153 kg/acre, yet the farmers in Kisoro used more fertilisers than those in Kabale (0%). This may imply that the Kabale soils are more conducive to potato production even with little or no fertilisers added, and may explain why, in a bid to increase Kisoro land productivity, the farmers there applied more inorganic fertilisers.

3.2 Comparative profitability assessment

At the average prices in the study area, pineapple and potato IP farmers make profits. While pineapple farmers obtain net returns of 127 000UShs/acre, potato farmers can earn 371 000 and 256 000UShs/acre (Table 2). The returns to variable costs from both potato-growing districts were positive, with 1.89 in Kabale (1.06 in Kisoro), indicating that every shilling invested in potato production returned about 1.9 shillings over and above the original investment in Kabale (and 1.1 shillings in Kisoro). These differences occurred because the Kisoro farmers invested more (as reflected in the costs of) labour and purchased inputs (planting material and fertilisers) compared to their counterparts in Kabale. When the non-cash costs (including the opportunity cost of family labour) are considered, then the returns to variable costs in Kisoro are 0.88 and those in Kabale are 1.46. Thus, holding other factors constant, potato production is more profitable in Kabale than in Kisoro, and pineapple growing is the least profitable of the three enterprises, albeit in different geographical regions.

Table 2: Gross margin analysis of enterprises

Variable	**Kabale**	**Kisoro**	**Ntungamo**
	Potato		Pineapple
Average area planted (acre)	0.68	0.8	0.81
Average output*	955.56	922.4	836
Average yield* (output/acre)	1 381	1 153	1 032
Gross income at average prices (UShs)	432 869	437 218	418 000
Gross income at average prices (UShs/acre)	625 593	546 522	516 000
Total variable cost, including hired and family labour (UShs/acre)	254 278	290 773	389 341
Net returns (UShs/acre)	371 315	255 749	126 659
Returns to variable costs (RVC)	1.46	0.88	0.33
Returns to labour	4.29	2.22	1.49
Unit cost of production (UShs/output)*	184.13	252.19	377.27

* Output measured as number of heads of pineapples, and kg for potato.

3.3 Seasonality effects

On average, potato prices were higher (474UShs/Kg) in Kisoro than in Kabale (453UShs/Kg). This could be due to the long distance to the markets for Kisoro farmers, which results in high transport costs that are reflected in the final price for potatoes. In Kabale, potato harvesting was done in July and August and again in December and January, while the peak potato-harvesting season in Kisoro occurs in May and June and in November and December. Price analysis revealed wide seasonal variation in potato prices between harvest and off-peak periods. Price margins of about 160UShs/400UShs/kg were observed in Kabale and Kisoro respectively. Pineapples are harvested almost all year round, although the major harvesting period is between July and October and also between December and February. As expected, prices were highest during the off-peak periods and plummeted during the peak harvesting periods. Pineapple prices varied from a low of 200UShs/head to 900UShs/head, corresponding to the peak harvest period and the off-peak seasons respectively (Figure 2).

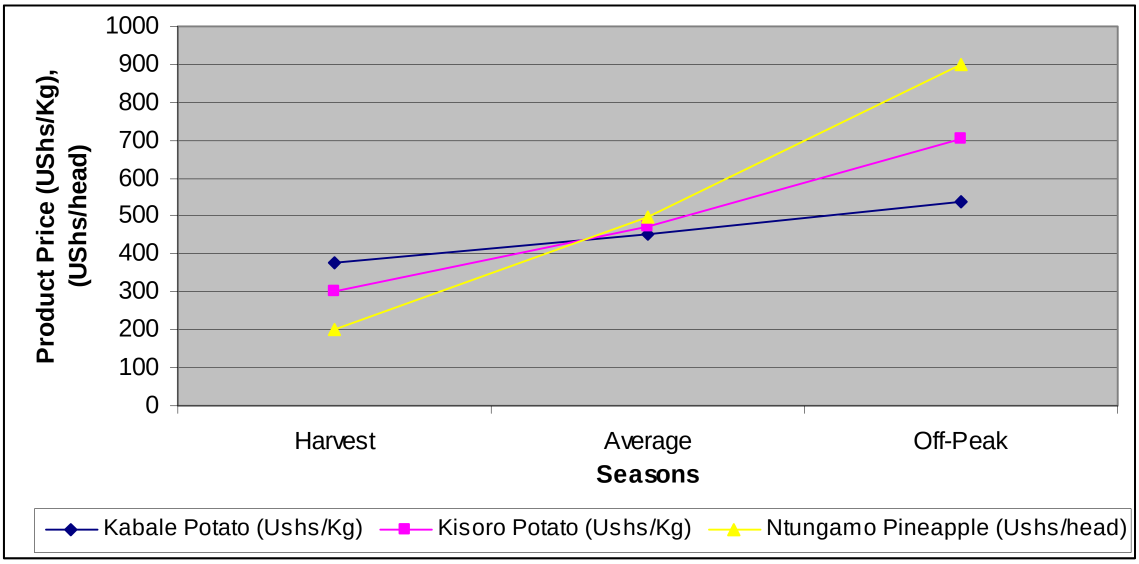

Figure 2: Seasonal price variation

The seasonality of pineapples, a highly perishable commodity, can be overcome by processing such as drying and juice extraction. Farmers usually sell farm-fresh pineapples because of limited product development alternatives and business development services. The average price of farm-fresh pineapple fruits, of 500UShs/head, implied that, on average, pineapple farmers made a profit of 126 659UShs/acre. However, farmers have an opportunity to make more money when they start selling sun-dried fruit, which fetches more per unit. Key informant sessions revealed that dried and packaged pineapples had the potential of earning 2 500UShs each. This implies that farmers would be able to get more returns per unit of factor input if they sold processed products in the off-peak periods. This can be provide very important leverage for supply and price fluctuation.

The potato farm-gate price also varied between seasons in Kabale and Kisoro. The off-peak farm-gate price was higher in Kisoro (705UShs/Kg) than in Kabale (378UShs/Kg). During the off-peak season, potatoes were scarcer in Kisoro than in Kabale because there is secondary production in the valley bottoms and swamps in the latter area. During the major harvest seasons, the farm-gate prices normally plummet to 378UShs/kg in Kabale and 300UShs/kg in Kisoro (Figure 2 above) because supply outmatches demand.

Across the regions, gross incomes and net returns were highest during the off-peak seasons and lowest at harvesting (Figure 3). Because of the low prices of pineapples at harvesting time (around 200UShs/head), the gross incomes are lower than for potatoes. In fact, if sold at harvest time, farmers obtain negative net returns from pineapples. However, off peak, the price of pineapples rises 350% above the harvest season price, conferring substantial increases in gross incomes, to about 540 000UShs/acre. These results highlight the importance of staggering harvesting seasons. This can be achieved through farm planning, involving planting in such a manner that different farmers' fields reach maturity at different times during the year. This measure is especially important since pineapple processing is still largely limited. However, due to the crop's high perishability, storage and preservation options, if available, would be exorbitantly expensive and out of reach of the ordinary farmer.

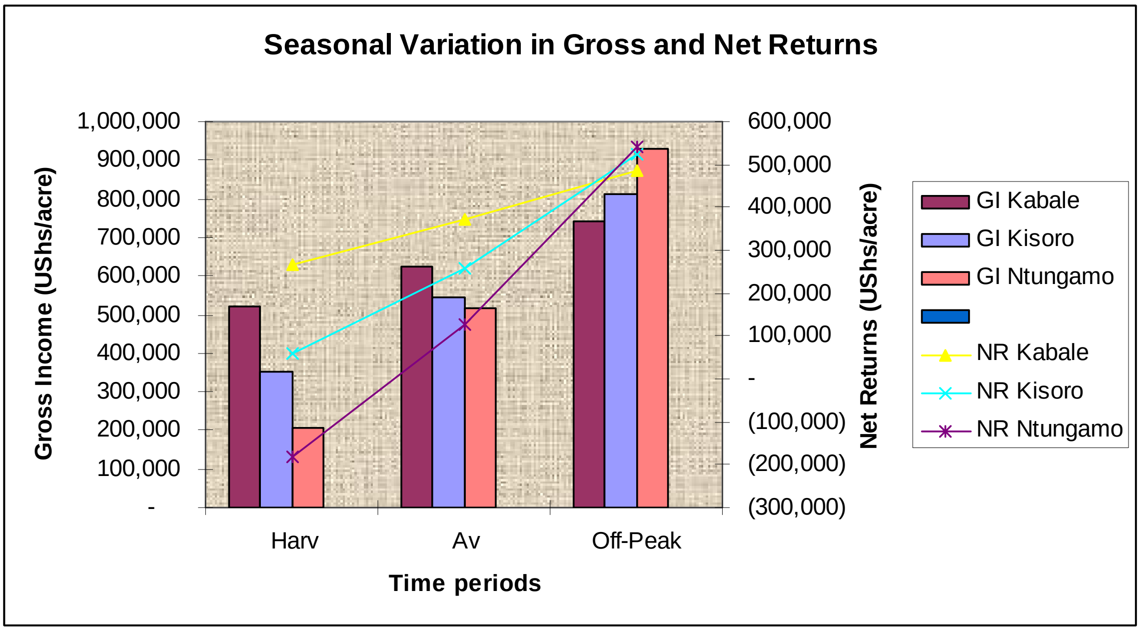

Figure 3: Gross margin analysis

3.4 Sensitivity analysis results

Tables 3 to 5 present the sensitivity analysis results for pineapples and potatoes. Regarding pineapples, and using the average price of 500UShs/head, a 50% reduction in yield from the average of 1,032 heads/acre to 516 heads/acre induces negative net returns. Likewise, at this average yield, a 50% reduction in price will result in negative net returns. In Kabale there are a wide range of prices and yields over which net returns remained positive at farm level, while the range of prices and yield levels that guarantee positive net returns is narrower in Kisoro. A 50% reduction in average yield and price leads to a negative net return of 117 239UShs/acre in Kabale. However, in Kisoro, a similar percentage decrease would result in a larger negative value, of 205 145UShs/acre. This result alludes to earlier findings that potato production is more profitable in Kabale than in Kisoro, given the prevailing input and output prices and land productivity.

Table 3: Sensitivity analysis for pineapples Ntungamo

(Using average price)		**250**	**300**	**350**	**400**	**450**	**500**	**550**	**600**	**650**	**700**	**750**
Yield (kg/acre)	% Change	-50%	-40%	-30%	-20%	-10%	-0%	+10%	+20%	+30%	+40%	+50%
516	-50%	(161 773)	(135 973)	(110 173)	(84 373)	(58 573)	(32 773)	(6 973)	18 827	44 627	70 427	96 227
619.2	-40%	(135 973)	(105 013)	(74 053)	(43 093)	(12 133)	18 827	49 787	80 747	111 707	142 667	173 627
722.4	-30%	(110 173)	(74 053)	(37 933)	(1 813)	34 307	70 427	106 547	142 667	178 787	214 907	251 027
825.6	-20%	(84 373)	(43 093)	(1 813)	39 467	80 747	122 027	163 307	204 587	245 867	287 147	328 427
928.8	-10%	(58 573)	(12 133)	34 307	80 747	127 187	173 627	220 067	266 507	312 947	359 387	405 827
1032	0%	(32 773)	18 827	70 427	122 027	173 627	225 227	276 827	328 427	380 027	431 627	483 227
1 135.2	+10%	(6 973)	49 787	106 547	163 307	220 067	276 827	333 587	390 347	447 107	503 867	560 627
1 238.4	+20%	18 827	80 747	142 667	204 587	266 507	328 427	390 347	452 267	514 187	576 107	638 027
1 341.6	+30%	44 627	111 707	178 787	245 867	312 947	380 027	447 107	514 187	581 267	648 347	715 427
1 444.8	+40%	70 427	142 667	214 907	287 147	359 387	431 627	503 867	576 107	648 347	720 587	792 827
1 548	+50%	96 227	173 627	251 027	328 427	405 827	483 227	560 627	638 027	715 427	792 827	870 227

Table 4: Sensitivity analysis for Kabale potato

(Using lowest price)		**189**	**226.8**	**264.6**	**302.4**	**340.2**	**378**	**415.8**	**453.6**	**491.4**	**529.2**	**567**
Yield (kg/acre)	% Change	-50%	-40%	-30%	-20%	-10%	-0%	+10%	+20%	+30%	+40%	+50%
690.5	-50%	(117 239)	(91 138)	(65 037)	(38 936)	(12 835)	13 266	39 367	65 468	91 569	117 670	143 771
828.6	-40%	(91 138)	(59 817)	(28 495)	2 826	34 147	65 468	96 789	128 110	159 431	190 752	222 073
966.7	-30%	(65 037)	(28 495)	8 046	44 587	81 128	117 670	154 211	190 752	227 293	263 835	300 376
1 104.8	-20%	(38 936)	2 826	44 587	86 349	128 110	169 871	211 633	253 394	295 156	336 917	378 679
1 242.9	-10%	(12 835)	34 147	81 128	128 110	175 092	222 073	269 055	316 036	363 018	410 000	456 981
1 381.0	0%	13 266	65 468	117 670	169 871	222 073	274 275	326 477	378 679	430 880	483 082	535 284
1 519.1	+10%	39 367	96 789	154 211	211 633	269 055	326 477	383 899	441 321	498 743	556 165	613 587
1 657.2	+20%	65 468	128 110	190 752	253 394	316 036	378 679	441 321	503 963	566 605	629 247	691 889
1 795.3	+30%	91 569	159 431	227 293	295 156	363 018	430 880	498 743	566 605	634 467	702 330	770 192
1 933.4	+40%	117 670	190 752	263 835	336 917	410 000	483 082	556 165	629 247	702 330	775 412	848 495
2 071.5	+50%	143 771	222 073	300 376	378 679	456 981	535 284	613 587	691 889	770 192	848 495	926 798

Table 5: Sensitivity analysis for Kisoro potato

(Using lowest price)		**152**	**182.4**	**212.8**	**243.2**	**273.6**	**304**	**334.4**	**364.8**	**395.2**	**425.6**	**456**
Yield (kg/acre)	% Change	-50%	-40%	-30%	-20%	-10%	-0%	+10%	+20%	+30%	+40%	+50%
576.5	-50%	(203 145)	(185 619)	(168 094)	(150 568)	(133 043)	(115 517)	(97 991)	(80 466)	(62 940)	(45 415)	(27 889)
691.8	-40%	(185 619)	(164 589)	(143 558)	(122 527)	(101 497)	(80 466)	(59 435)	(38 404)	(17 374)	3 657	24 688
807.1	-30%	(168 094)	(143 558)	(119 022)	(94 486)	(69 950)	(45 415)	(20 879)	3 657	28 193	52 729	77 265
922.4	-20%	(150 568)	(122 527)	(94 486)	(66 445)	(38 404)	(10 363)	17 678	45 719	73 759	101 800	129 841
1 037.7	-10%	(133 043)	(101 497)	(69 950)	(38 404)	(6 858)	24 688	56 234	87 780	119 326	150 872	182 418
1 153.0	0%	(115 517)	(80 466)	(45 415)	(10 363)	24 688	59 739	94 790	129 841	164 893	199 944	234 995
1 268.3	+10%	(97 991)	(59 435)	(20 879)	17 678	56 234	94 790	133 347	171 903	210 459	249 015	287 572
1 383.6	+20%	(80 466)	(38 404)	3 657	45 719	87 780	129 841	171 903	213 964	256 026	298 087	340 149
1 498.9	+30%	(62 940)	(17 374)	28 193	73 759	119 326	164 893	210 459	256 026	301 592	347 159	392 725
1 614.2	+40%	(45 415)	3 657	52 729	101 800	150 872	199 944	249 015	298 087	347 159	396 231	445 302
1 729.5	+50%	(27 889)	24 688	77 265	129 841	182 418	234 995	287 572	340 149	392 725	445 302	497 879

3.5 Technical efficiency of potato-growing farms

Table 6 presents the results of the determinants of potato production using a Cobb-Douglas functional form estimated with OLS, robust regressions and stochastic frontier models. In all three models, the magnitude and direction of the covariates is consistent, suggesting robustness in the estimation procedures. Controlling for all other inputs used in potato production, the cost of planting material and female labour significantly and positively affect potato production (at the 1% and 10% levels respectively).

Table 6: Determinants of potato yield

Logpotyield	**Loglinear**		**Robust regression**		**Stochastic frontier**	
	Coef.	St. dev.	Coef.	St. dev.	Coef.	St dev.
Lnfemlabor	0.041	0.024*	0.037	0.025	0.041	0.023*
Lntotmalelabor	0.011	0.036	0.013	0.037	0.011	0.035
Lntotchem	-0.022	0.024	-0.033	0.025	-0.022	0.024
Lntotplanting material	0.165	0.056***	0.158	0.058***	0.166	0.054***
Lntotmanure	0.005	0.035	0.008	0.037	0.004	0.034
Bufundi[1]	0.092	0.354	0.041	0.365	0.084	0.344
Wp_Vicv	-0.299	0.336	-0.288	0.346	-0.302	0.320
Wp_RwaV[2]	0.007	0.306	0.090	0.324	0.009	0.289
_cons	4.802	0.716***	4.901	0.739***	5.209	1.363***
N	108		108		108	108
Prob > F	0.0771		0.1164			
R^2	0.142		0.130			
Prob > Chi^2					0.0346	
Log likelihood					-153.559	

1. Chahi IP dropped to avoid multicollinearity
2. Kinigi variety dropped to avoid multicollinearity

The result for female labour is consistent with our findings in Table 8, where female farmers were found to be more efficient than males in potato production. The results for planting material strongly suggest that the quality of the seed material as reflected by the cost is a major constraint in potato production in SW Uganda, therefore interventions that provide these planting materials to the farmers or that ease the farmers' liquidity constraints to access high-quality planting materials will greatly boost potato production in these areas.

Table 7: Descriptive results: efficiency analysis

	Efficiency classes		
Variable	Low	Medium	High
Technical efficiency score	0.627	0.697	0.750
Total potato yield (kg/acre)	476.473 (322.63)	1080.733 (382.19)	4109.23 (3660.49)
Total potato area (Acres)	1.101 (1.051)	0.657 (0.515)	0.53 (0.387)

(In parentheses: standard deviations)

Table 7 shows the descriptive results for technical efficiency among potato farmers. All the farms in the sample were technically inefficient. Efficiency scores ranged from 0.51 to 0.82, with an overall mean of 0.69, and were normally distributed within those limits (see Figure 4). A comparative class analysis of efficiency scores using Bartlett's test for equal variance was significant at the 1% level, indicating that there were significant differences in three distinct efficiency classes. Farmers in the low-efficiency class had a mean efficiency of 62.7%, while the most efficient farmers had a mean of 75%.

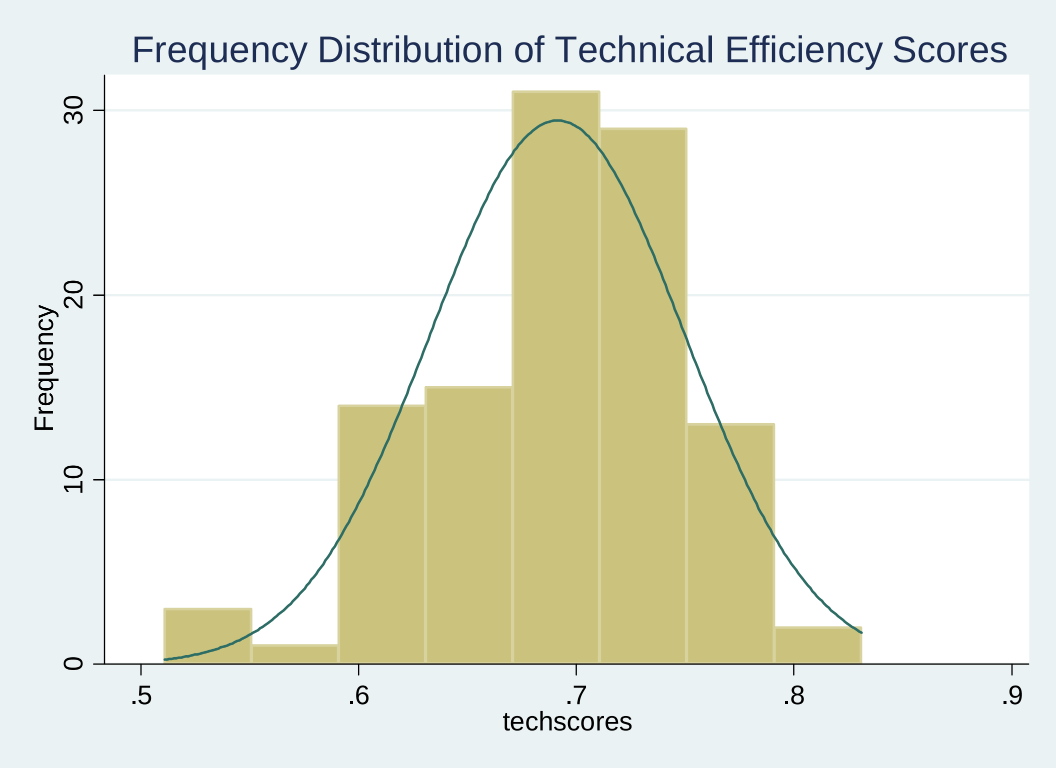

Figure 4: Distribution of efficiency scores

One-way analysis of efficiency scores and potato yield indicated that the more efficient farmers had higher yields and smaller acreage under potato. This result is consistent with the findings by Tchale (2009), who observed an inverse relationship between crop value per hectare and land size. Helfand and Levine (2004) found a non-linear relationship, negative for small farm sizes, but positive as farm size increased. This seems to suggest that, before a critical threshold is attained, production efficiency decreases with size, implying that smaller farms are more efficient, consistent with theories of intensification and the need to optimise returns from a smaller area when land is a constraint. Intensive cultivation has been a major characteristic of farming in the study area due to a lack of land and the resulting land fragmentation arising from high population density (Low 2000).

There were significant differences in scores between farmers who considered potatoes a profitable enterprise and those who did not. Knowledge about the soil-improving benefits of fertilisers did not significantly determine efficiency scores. No significant difference in efficiency scores was found across the IPs. Technical efficiency was similar across the three potato-growing areas, which can be an indicator of the randomness of the sampling procedure. For project interventions, the SSACP site selection procedure (Buruchara *et al.*, this volume) aimed at identifying regions with similar conditions. The three distinct innovation platforms in two districts lie in the highland areas of southwestern Uganda, with similar geographical capitals. The implication of this is that agricultural production efficiency is not expected to vary based on geographical location (within the IPs), but perhaps on a different set of variables while controlling for geographical setting. The region invariance in efficiency results suggests that interventions aimed at improving agricultural production efficiency can be expected to have comparable effects, regardless of the IP.

3.6 Results of drivers for efficiency

Table 8 presents the results of the OLS and Tobit model estimation, as well as results from a robust regression model. The OLS and Tobit model results are not different, which indicates that the dependent variable – efficiency scores – was not censored, therefore suggesting that OLS is an unbiased estimator for this data.

In all three models the farmer's perception of enterprise profitability is a significant contributor to production efficiency. Farmers who perceived potatoes to be the most profitable enterprise also realised high efficiency in potato production. This finding was perhaps because perceptions, attitudes and shared beliefs are important stimulants for processes towards achieving and shaping the desired outcome (Habbershon & Astrachan 1997; Cormier *et al.* 2004).

Table 8: Factors determining potato production efficiency

Variable	Tobit	OLS	Robust regression
Age	0.000	0.000	0.000
Gen	0.004	0.004	-0.042*
Educ	0.002	0.002	0.002*
HHSize	0.003***	0.003	0.001
FPP	0.041*	0.041*	0.032*
Constant	0.652*	0.652*	0.673*
Sigma_cons	0.053*		
F(5,102)		4.48	
R-Squared		0.180	
Log Likelihood	164.5067		
Prob > chi^2	0.0007		
N	108	108	108
No. of left censored observations	0		
No. of uncensored observations	108		
No. of right censored observations	0		

Note: * significance at 1%, ** significance at 5%, *** significance at 10%

The coefficient estimates for age are statistically not different from zero in any of the three models, implying that the age of the farmer had no effect on production efficiency. A recent study in Uganda (Asiimwe 2010) found similar results in relation to the technical efficiency of rice producers. Dhungana *et al.* (2004) found that age had a negative effect (but a positive quadratic effect) on the efficiency of rice farmers in Nepal. The findings of the current study suggest that, in the study area, young and old farmers use the same farming practices and any agricultural efficiency-enhancing programmes – such as productivity-improving technologies – should be introduced without pre-selecting potential beneficiaries on the basis of age.

The coefficient for gender is statistically different from zero and negative in direction. The implication is that female-headed households are more efficient than those headed by men. Similar results can be found in the classic study by Quisumbing (1996), who used various efficiency measures to confirm that female-headed households were more efficient at agricultural production. The results show that education is a necessary driver of efficiency. Each additional year of education is associated with a 0.002 increase in efficiency score, other factors being constant. Education imparts knowledge of better farming practices, including allocation of inputs and identification of better input markets. Similar results have been found by Jamison and Moock (1984) in Nepal; Kumbhakar *et al.* (1989) in their study of dairy farmers in Utah; Phillips (1994) in a meta-analysis of studies in Asia and Latin America; and Bravo-Ureta and Pinheiro (1993) in a meta-analysis of agricultural efficiency across 14 countries. In a more recent study on rice efficiency in Uganda, however, Hyuha *et al.* (2007) found that the level of education was negatively related to efficiency and suggested the introduction of farming improvement programmes to younger generations as a way of improving future production efficiency in rice.

4. Conclusions and Recommendations

The focus of this study was to estimate the profitability of potato and pineapple enterprises in SW Uganda. The results indicate that both enterprises are profitable, returning more to the farmer than the original investment in terms of purchased inputs and labour. Returns on variable costs were 1.9 in Kabale, 1.1 in Kisoro and 0.33 in Ntungamo, indicating that pineapple was the least profitable, albeit in different geographical locations. Pineapple farmers obtained net returns of 127 000UShs/acre. The returns to family and hired labour for pineapples was determined as 1.49, implying that each shilling worth of labour invested in organic pineapple enterprises returned one and a half shillings, other factors being constant.

Seasonality effects were seen to have an impact on pineapple gross returns. Pineapple prices were lower than those for potatoes during the peak seasons, but off-peak pineapple prices rose 350% above the peak price, resulting in a substantial increase in gross incomes to about 540 000UShs/acre.

Further analysis indicates that all potato farms in the study area were operating inefficiently, with an average efficiency score of 0.69, indicating that there was room for an improvement in efficiency in potato farming. More efficient farms were associated with higher land productivity but low average potato acreage, consistent with theories on economies of scale. Compared to males, female farmers were more efficient, which may be related to the need to optimally utilise their limited resource endowment. The low efficiency scores observed in the study area generally highlight the relative inefficiency that characterises smallholder agriculture in developing countries, particularly in Uganda.

Regarding education, our results show that, as expected, more educated farmers are more efficient in potato production. This evidence supports and further augments the current government programmes for universal secondary and primary education, which will have positive externalities and payoffs in agricultural production in rural areas. This finding demonstrates the positive spill-overs from public education investments to efficient agricultural production in SW Uganda, a finding that can be extrapolated to other areas with similar socio-economic and agro-ecological conditions.

Most studies only identify whether or not enterprises are profitable and paint an incomplete picture if the profitability assessment is not supplemented with an efficiency analysis. It could be of interest to researchers to determine the profitability of farmers' enterprises and to go further to determine whether those farmers obtain the most they can, given their resources. Further, this study's results on the effects of both education and gender on efficiency underscore the importance of targeting education/training programmes to female farmers if agricultural efficiency is to be improved to achieve food self-sustenance and food security. Pineapple farmers should explore value-adding avenues in order to reduce the risks associated with postharvest losses, and also take advantage of better prices during the off-peak season. In addition, options for increasing land productivity through use of soil fertility-enhancing technologies should be emphasised.

References

Adil SA, Chattha MWA, Hassan S & Maqbool A, 2007a. Economics of vegetable production by farm location. Pakistan Journal of Agricultural Sciences 44(1): 179–183.
Adil SA, Chattha MWA, Hassan S & Maqbool A, 2007b. Profitability analysis of summer vegetables by farm size. Pakistan Journal of Agricultural Sciences 44(1): 184–188.

Ahmad B, Hassan S, Bakhsh K & Ahmad W, 2005. Profitability and various constraints in potato cultivation. Pakistan Journal of Agricultural Sciences 42(3-4): 68–73.

Asiimwe KJ, 2010. Technical efficiency of upland rice producers in South Western Uganda. Unpublished MSc thesis, Makerere University, Kampala, Uganda.

Bravo-Ureta BE & Pinheiro AE, 1993. Efficiency analysis of developing country agriculture: A review of the frontier function literature. Agricultural and Resource Economics Review 22: 88–101.

Cormier D, Gordon IM & Magman M, 2004. Corporate environmental disclosure: Contrasting management's perceptions with reality. Journal of Business Ethics 49(2): 143–165.

Dhungana BR, Nuthall PL & Nartea GV, 2004. Measuring the economic inefficiency of Nepalese rice farms using data envelopment analysis. The Australian Journal of Agricultural and Resource Economics 48(2): 347–369.

Habbershon TG & Astrachan JH, 1997. Research note: Perceptions are reality: How family meetings lead to collective action. Family Business Review 10(1): 37–52.

Helfand SM & Levine ES, 2004. Farm size and determinants of productive efficiency in Brazilian Center West. Current Issues in the Economics of Agriculture, Food, and Resources: Reshaping Agriculture's Contributions to Society Agricultural Economics, 31, 241–249.

Hyuha TS, Bashaasha B, Nkonya E & Kraybill D, 2007. Analysis of profit inefficiency in rice production in Eastern and Northern Uganda. African Crop Science Journal 15(4): 243–253.

Jamison DT & Moock PR, 1984. Farmer education and farm efficiency in Nepal: The role of schooling, extension services, and cognitive skills. World Development 12(1): 67−86.

Krasachat W, 2011. Measurement of technical efficiency in Thai agricultural production. The Chao Phraya Delta: Historical development, dynamics and challenges of Thailand's Rice Bowl.

Kumbhakar SC, Biswas B & Bailey D, 1989. A study of economic efficiency of Utah dairy farmers: A system approach. The Review of Economics and Statistics 71(4): 595–604.

Low J, 2000. Prospects for Sustaining Potato and Sweet Potato Cropping Systems in the Densely Populated Highlands of Southwest Uganda. International Potato Center, Social Science Department Working Paper No. 2000-1.

Mwang'ombe JG, 2008. The potato value chain in Kenya and Uganda. DBA Assignment, Maastricht School of Management.

Ogundele OO & Okuruwa VO, 2006. Technical efficiency differentials in rice production technologies in Nigeria. Research paper 154, Africa Research Consortium, Nairobi.

Phillips JM, 1994. Farmer education and farmer efficiency: A meta-analysis. Economic Development and Cultural Change 43(1): 149–165.

Quisumbing AR, 1996. Male-female differences in agricultural productivity: Methodological issues and empirical evidence. World Development 24(10): 1579−1595.

Salami A, Kamara AB & Brixiova Z, 2010. Smallholder agriculture in East Africa: Trends, constraints and opportunities. Working Paper Series No. 105. African Development Bank, Tunis, Tunisia.

Tchale H, 2009. The efficiency of smallholder agriculture in Malawi. African Journal of Agricultural and Resource Economics 3(2): 101–121.