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Determinants of the Use of Certified Seed Potato among Smallholder Farmers: The Case of Potato Growers in Central and Eastern Kenya

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Abstract: Potato yields in sub-Saharan Africa remain very low compared with those of developed countries. Yet potato is major food staple and source of income to the predominantly smallholder growing households in the tropical highlands of this region. A major cause of the low potato yields is the use of poor quality seed potato. This paper examines the factors determining the decision to use certified seed potato (CSP), as well as the intensity of its use, among potato growers with access to it. We focused on potato growers in the central highlands of Kenya and used regression analysis to test hypotheses relating to potential impediments of CSP use. The study found that the distance to the market (a proxy for transaction costs), household food insecurity, and asset endowment affect the decision to use CSP. However, the effect of the intensity of use of CSP depends on how the intensity variable is defined. Several other control variables also affect the decision and extent of CSP use. The study concludes that transaction costs, asset endowment, and household food insecurity play a major role in the decision by smallholder potato farmers to use CSP and the extent to which they do so. We also discuss the policy implications of the findings.

Keywords: smallholder farmers; seed systems; certified seed potato; use and intensity of use; Kenya

1. Introduction

Potato is a staple food and cash crop in the tropical highland regions of sub-Saharan Africa, where it is grown both as a horticultural crop, due to its high value, and a food security crop. Globally, potato ranks fourth after maize, rice, and wheat [1]. In Kenya, it is the second most important food crop after maize [2,3] and a major food staple among potato growing communities. It thus plays an important role in improving household food security. An estimated 800,000 farmers grow potato in Kenya [4], while over 2.5 million people in Kenya are employed along the potato value chain as, among other things, traders and processors [5]. Consequently, potato additionally contributes to poverty alleviation through income generation in both urban and rural households [6].

Potato production in Kenya is dominated by smallholder farmers, with a land size below 5 acres (1 hectare of land is equivalent to approximately 2.471 acres) [7]. Its production is mainly concentrated in the highlands of Central, Eastern, and Rift Valley provinces, especially in districts around Mt. Kenya, the Aberdare range, Mt Elgon, the edges of the Rift Valley, and the Mau escarpment, in altitudes ranging from 1500 to 3000 m above sea level [4]. These areas have some of the most productive agricultural lands in Kenya, most of which are characterized by deep fertile volcanic soils and 1100–2700 mm of rainfall per year [8]. The tropical humid climate enables the production of potato mainly through rainfed farming. However, despite the suitable soils and climate, potato yields in the tropical highlands remain very low and typically fluctuate between 8 and 10 tons per hectare. These yields are very low, compared with yields of 40 tons per hectare obtained by developed country farmers [2,9].

The low potato yields in the tropical highlands of Africa are largely attributed to pests and diseases, particularly late blight, bacterial wilt, and viruses, and to the inadequate supply and farmer access to quality seed [2,5]. The latter problem results in the use and reuse of poor-quality, pest- and disease-infested seeds. Low yields, on the other hand, impedes household commercialization and confines smallholder farmers in subsistence agriculture [10,11], hence limiting small farm sector development and ultimately entrenching food insecurity and poverty.

The need to arrest the decline in potato yields has been a major goal of policy makers in the tropical highland regions of Africa, including Kenya, Tanzania, Rwanda, and Uganda. For instance, the government of Tanzania, jointly with Ministry of Agriculture, recently invested in a three-year project intended to develop the potato seed sector and reverse yield declines in the southern highland region. In Kenya, this effort is exemplified by the recent formulation of a multi-partner potato strategy [12] for Nyandarua County, a leading potato producing county in Kenya, in January 2015. An earlier strategy, first piloted in Kenya, was the establishment of a rapid seed multiplication technique, commonly known as the "3G" technique, which produces quality seed using fewer generations of field multiplication [13]. Through this technique, Kisima Farm Ltd., a private sector firm, located in Meru, Central Kenya, has, since 2009, been multiplying/bulking (Kisima Farm Ltd. does not produce own seed. Instead, it uses rapid multiplication technique to bulk early generation seed into farmer's seed potato) high quality certified seed potato (CSP) for sale to smallholder farmers. This private sector multiplication of seed potato has increased the supply of quality seed and improved farmers' physical access to seed. However, the majority of farmers still use their own or recycled seed. This paper examines the adoption of CSP among farmers located in close proximity to Kisima Farm Ltd. It especially addresses two interrelated research questions:

(1) What are the determinants of the farmer's decision to use CSP?

(2) Given the decision to use CSP, what factors affect the intensity of the use of CSP?

We tested three hypotheses relating to the decision and intensity of the use of CSP. First, for *Hypothesis 1*, we tested whether the decision and extent of the use of CSP is affected by the distance to the source of the seed. Seed potato is bulky; hence, movement over a long distance is likely to entail high transportation and transaction costs. Hence, it is hypothesized that distance from the farm to the seed potato source has a negative effect on both the decision and extent of the use of CSP. Second, for *Hypothesis 2*, we tested the effect of asset endowment on the decision and extent of using CSP. CSP is by all means expensive. The high cost of CSP is expected to discourage its use. Thus, we hypothesize that farmers who are better off in terms of financial and other assets are more likely to use CSP than their counterparts. Lastly, in order to examine if food insecurity status of the household reduces the use of quality seed, we tested, for *Hypothesis 3*, the effect of self-perceived household food insecurity on the use of CSP. Indeed, household food insecurity can affect the use of CSP through various ways; chief among them is the diversion of funds that would be invested in CSP into food purchases. The results of each of these tests are presented in Section 4.

2. The Study Context

The majority of smallholder farmers have poor access to CSP and hence depend on seed from their own sources or on seed purchased from neighbors or in local markets. Data from this study indicate that up to 65% of the respondents replace their seed potato mainly with those from neighbors and local market purchases. Usually more than 95% of seed purchased locally are of low quality.

Past studies draw a direct link between poor access to CSP and the low yields obtained by potato farmers in sub-Saharan Africa [14–16]. These studies argue that the low yield results from the accumulation of seed-borne diseases, especially bacterial, fungal, and viral diseases, which have been associated with severe degeneration in seed quality globally [17–19]. Studies further indicate the common farmers' crop protection practices—especially the use of pesticides—are ineffective against these diseases [6,20,21]. Consequently, the majority of smallholder farmers realize very low average yields of 8 to 10 $t{\cdot}ha^{-1}$, which is way below the attainable yields of 20 to 30 $t{\cdot}ha^{-1}$. To tackle the problem of access to CSP, the International Potato Center (CIP) has, since 2009, forged public-private-producer partnerships to increase the supply of CSP and farmer access to such seed. The technique produces quality seed in three generations of field multiplication, as opposed to the conventional five to seven generations [13]. The private sector partner, Kisima Farm Ltd., led the multiplication of seed potato using the rapid multiplication techniques known as the three-generation (3G) approach. The farm is based within the major producing area of the Mt Kenya region, hence reducing the distance farmers in this region have to transport seed (prior to establishment of Kisima Farm seed potato business, farmers in Mt Kenya region relied on seed produced in Tigoni or Molo, both of which are located more than 300 km away).

Past estimates indicated that the farm was producing 1000 tons of CSP per annum [22]. It sold most of this seed to smallholder farmers within a radius of 30 km. Farmers who were far off organized themselves into groups and imported CSP from the farm in bulk, in order to reduce per-unit costs of CSP. The farm sold CSP at 47 US cents per kilogram, compared with 24 US cents/kg and 22 US cents/kg for seed potato from neighbors and open market sources, respectively [22]. The varieties it produces are Kenya Mpya, Sherehekea, Asante, and Tigoni White. The Farm's operation has undoubtedly increased the availability of seed potato in the producing areas. However, it is still unclear as to whether smallholder farmers are taking advantage of this to use quality, rather than non-certified seed, and as to what the factors that affect such a decision are.

3. Study Methods

3.1. Factors Affecting the Decision to Use Quality Seed Potato

A household's decision to adopt or use a new technology is usually affected by the benefits and costs of doing so [11,23]. Adoption literature [24,25] posits that such a decision is a function of several farmer and farm-level characteristics, capital and asset endowment factors, institutional factors, and various fixed and quasi-fixed factors.

In choosing to use quality seed potato, farmers typically have to make two consecutive decisions: (1) whether to plant CSP during the two seasons or not; (2) contingent on the decision to plant CSP, how many of the different CSP varieties should be planted. The first decision is normally analyzed using binary choice models, while the second typically employs count data models. This study applied the binary Probit regression model to assess the factors that influence the decision to use CSP. The Probit regression model was chosen over the others because of its good properties, especially the assumption of normal distribution [26].

The Probit regression model used is expressed [27] as follows:

$$P = \frac{e^{z}}{1 + e^{\sigma}} \tag{1}$$

where P is the probability that a household used CSP, and σ is a latent variable that takes the value of 1 if the farmer used quality seed and 0 if not.

Transformation of this model yields the following:

$$\sigma = \ln\left(\frac{\mathrm{P}}{1 - \mathrm{P}}\right) \tag{2}$$

$$\sigma = F\,(X, V, T, K, z) + \epsilon \tag{3}$$

X is a vector of inputs such as fertilizer, manure, and other chemicals, namely, insecticides and fungicides used by the farmer, *V* is a vector of embodied potato varietal traits such as good taste, ease of cooking, higher pest and disease tolerance, early maturity and high-yielding ability; *T* is the total labor requirement, comprising family labor and hired labor. Lastly, *K* and *z* are fixed capital inputs that represent the asset owned and institutional factors including membership to farmer organization and access to credit, respectively, and ε is the stochastic term, assumed to have a normal distribution.

Based on Equation (3), we derive implicit functional form of the empirical Probit regression model used to assess the drivers of the first decision (i.e., likelihood of farmer deciding to plant quality seed potato or not). The derived empirical model can be expressed as:

$$\begin{aligned} qseed = f(&gender, hhdsize, lnage, phone, experience, memgrp, lnland, lndistmkt, \\ &lndistkisima, lndistagric, lnasset, pest, blight, taste, market, risk, foodsec) + \varepsilon \end{aligned} \quad (4)$$

The variables, their definitions and their hypothesized signs are presented in Table 1.

Table 1. Variables used in the models and their hypothesized effects on the use of certified seed potato.

Variable	Description of Variable	Hypothesized Effect
qseed	Use of Quality seed potato (1 = yes; 0 = otherwise)	Dependent variable
Csp_var	Number of CSP varieties planted, expressed as count values of 0, 1, 2, 3, or 4	Dependent variable
land_csp	Area planted under all the four CSP varieties	Dependent variable
gender	Gender of the farmer (1 = male; 0 = otherwise)	+/−
hhdsize	Number of household members	−
lnage	Natural logarithm of respondent's age measured in years	+/−
phone	Farmer owns a mobile phone (1 = yes; 0 = otherwise)	+
experience	Number of years of growing potato	+
memgrp	Farmer is a member of a farmer organization (1 = yes; 0 = otherwise)	+
lnland	Natural logarithm of the area of land a farmer owns in acres	+
lndistmkt	Natural logarithm of distance to the nearest market in walking minutes	−
lndistkisima	Natural logarithm of distance to Kisima Farm in kilometers	−
lndistagric	Natural logarithm of distance to the nearest agricultural office in walking minutes	−
Inasset	Natural logarithm of the value of physical assets (*asset*) in Kenya Shillings	+
pest	Farmer's perception and ranking (1 = poor, 5 = very good) of quality seed's tolerance to pests	+
blight	Farmer's perception and ranking (1 = poor, 5 = very good) of quality seed's tolerance to potato blight disease	+
taste	taste is a farmer's Likert ranking (1 = poor, 5 = very good) of the taste of quality seed varieties	+
market	market is farmers Likert ranking (1 = poor, 5 = very good) of the market for potato from quality seed	+
risk	If a farmer perceives ware potato market as very risky (1 = yes; 0 = otherwise)	−
foodsec	Food insecurity prevalence in farmer's household measured using household food insecurity access score that ranges from 1 to 27	−
ε	Is the stochastic term	

The second decision, namely, how many varieties of CSP to plant, often referred to as the extent/degree/intensity of adoption, is normally analyzed using count data models [28]. This is because the dependent variable is defined as the count or number of CSP varieties planted by the farmer and is hence a discrete non-negative count variable [29,30]. Therefore, the Poisson regression technique was used. In total, four varieties were included in the analysis, namely, Asante, Sherehekea, Tigoni White, and Kenya Mpya. Thus, the dependent variable, defined as the number of CSP varieties planted, took the values of 0, 1, 2, 3, or 4. The independent variables are similar to those in Equation (4) above.

The derived empirical model for estimating the extent/ degree/intensity of adoption can be expressed as:

$$csp\_var = f(gender, hhdsize, lnage, phone, experience, memgrp, lnland, lndistmkt, \\ lndistkisima, lndistagric, lnasset, pest, blight, taste, market, risk, foodsec) + \varepsilon \quad (5)$$

Both the Probit and Poisson regression models were estimated using the survey regression technique, with the village as the cluster. The technique has the advantage of controlling for the clustering effect of the variance at the village level. It therefore improves the efficiency of the parameter estimates in the regression model.

3.2. Area under Certified Seed Potato

In addition to the Poisson regression model that focused on the number of CSP varieties planted, this study also examined the extent of adoption of CSP by estimating a Tobit regression model. The dependent variable used in this model was the area planted under all the four CSP varieties (namely Asante, Sherehekea, Tigoni White, and Kenya Mpya). The area planted under these varieties is a continuous variable but is censored at zero for farmers who did not purchase and plant any of the CSP varieties. That is, for farmers who did not purchase and plant any of the CSP varieties, the area planted takes a value of zero. The explanatory variables used are the same as those in Equation (4), and thus the empirical model can be expressed as:

$$land\_csp = f(gender, hhdsize, lnage, phone, experience, memgrp, lnland, lndistmkt, \\ lndistkisima, lndistagric, lnasset, pest, blight, taste, market, risk, foodsec) + \varepsilon \quad (6)$$

3.3. Measurement of Household Food Insecurity

In order to test the effect of household food insecurity on the use of CSP, we needed a proxy measure of food insecurity. Although household food insecurity has received much attention in the literature, its empirical assessment and measurement remain very difficult [31,32]. Most common quantitative estimates of food insecurity have therefore relied on anthropometric or dietary recall data to derive a measure of household food insecurity. Unfortunately, such data tend to be complicated and costly to collect [33]. This study therefore used the Household Food Insecurity Access Scale (HFIAS) to measure food insecurity. HFIAS was developed by the Food and Nutrition Technical Assistance project of the United States International Development Agency. It focuses on the food access component of food insecurity [33,34]. The computation of the household food insecurity score (*foodsec*) is found in [34].

3.4. Sampling Procedure and Data

The data used in this study were collected from six districts of the Mt Kenya region, namely, Buuri, Igembe Central, Igembe South, Laikipia East, Meru Central, and Tigania East due to their proximity to the CSP source, i.e., Kisima Farm Ltd. In each of the districts, the study focused on the villages with smallholder potato farmers who had used CSP from Kisima Farm during any of the four seasons of two years preceding the study, namely, 2012 and 2013.

The study respondents were selected as follows: First, a list of all the villages with farmers who planted CSP from Kisima Farm was obtained, and the villages that had fewer than 12 CSP purchasers were dropped (this was done mainly to avoid an oversampling of respondents in villages with very few purchasers). This procedure resulted in the selection of the 21 villages in Buuri, one in Igembe Central, one in Igembe South, two in Laikipia East, five in Meru Central, and four in Tigania East. A total of 34 villages were therefore selected from the six study districts. Second, for each village, a list of all the farmers who had planted CSP from Kisima Farm Ltd during the two years prior to the study was drawn with the help of local administrators, especially the village heads and contact farmers. A second list of potato growers who used other types of seed potato was also drawn. Third, 12 respondents were randomly selected from the two lists, in each village, using a probability proportionate to the size sampling technique. That is, more farmers were sampled from the list with more names, and vice versa. This procedure resulted in the selection of 408 farmers: 167 CSP and 241 non-users.

Eight trained enumerators collected the data from the selected farmers through personal interviews using a pre-tested questionnaire. The interviews ran from March to May 2014. The data were entered in SPSS and analyzed using Stata.

4. Results

4.1. Characterization of Study Respondents

Table 2 presents the demographic characteristics of users and non-users of CSP stratified by the gender of the respondent. The mean age of all the respondents was 49 years, but the average age of male respondents was significantly higher than for the female respondents. On average, the respondents had eight years of education, implying that the majority had only attained primary level of schooling.

Users of CSP had a significantly higher average level of education than the non-users. Specifically, the results indicate that the users of CSP had, on average, about nine years of schooling, which is equivalent to post-primary education, as compared with their counterparts that had on average an equivalent of primary school. This finding is in line with the adoption literature that suggests that education increases human capital and skills, and enhances the likelihood of the uptake of new technologies [35]. Users and non-users of CSP also differed in terms of ownership of mobile phones, an important communication tool and asset. On average, 96% of the users of CSP owned or had access to mobile phones. This finding has significance in terms of market access [36]. It has been found that owning mobile phones reduces the transaction costs of market access by making it easier for a farmer to find input sellers, produce buyers more cheaply, or both [37]. It was also found that possession of mobile phones facilitates access to distant markets by reducing transaction costs. Results further show that the study respondents had, on average, grown potato for 19 years and therefore had considerable experience in potato farming. There was, however, no difference in potato growing experience between purchasers and non-purchasers, and between male and female farmers.

Table 2. Socioeconomic characteristics of the study respondents.

	Users [a] (N = 167)	Non–Users [b] (N = 241)	
	Mean	**Mean**	**Mean Diff [a–b]**
Variable	**(SD)**	**(SD)**	**(*t*-Value)**
distkisima	27.31 −26.51	32.7 −29.24	−5.393 * (−1.937)
distagric	101.56 −111.58	79.67 −81.28	21.891 ** −2.168
age	49.08 −12.53	48.49 −13.89	0.59 −0.45
gender	0.55 −0.5	0.47 −0.5	0.08 −1.63
education	8.92 −3.86	7.89 −3.76	1.03 *** −2.69
experience	19.72 −12.41	18.62 −12.64	1.1 −0.87
landowned	2.13 −1.96	0.16 −0.84	1.98 ***
mobiphone	96 −0.19	89 −0.32	8.00 *** −3.05
hhdsize	4.34 −1.59	4.25 −1.73	0.08 −0.49
risk	0.293 −0.035	0.224 −0.027	0.069 −1.59
pest	0.401 −0.038	0.51 −0.032	−0.109 ** −2.181
taste	4.214 −0.081	4.304 −0.062	−0.09 −0.898
market	4.55 −0.06	4.42 −0.059	−0.067 −1.522
blight	4.29 −0.082	3.745 −0.394	0.544 −1.14

Standard errors and *t*-values are in parentheses; *, **, and *** significant at 10%, 5%, and 1% respectively.

4.2. Factors Affecting the Decision to Use Certified Seed Potato

The results of the survey Probit regression model estimated to assess the factors affecting the decision to use CSP or not are presented in Table 2, columns 2 and 3. It has an F-statistic and p-value of 3.65 and 0.005, respectively, indicating that the explanatory variables included in the model captured most of the variability in the decision to plant CSP. As hypothesized, in *Hypothesis 1*, the results show that the distance to the source of certified seed potato (that is, Kisima Farm Ltd.) indeed significantly affects, albeit weakly, the decision to use CSP. Specifically, the higher the distance to the source of CSP, the lower the likelihood that a farmer will use CSP. The finding that farmers who live far away from the seed potato source are less likely to use CSP is in line with the results of the descriptive analysis above. It also corroborates past findings [36,38] that suggest that being located far from the input market increases the transaction costs and can dampen incentives to use CSP. In addition, as stated in *Hypothesis 3*, the decision to use CSP is also negatively affected by household food insecurity. Specifically, the higher the level of household food insecurity, the lower the likelihood is that a respondent will use CSP. This finding therefore lends support to the argument that food insecure households are not likely to spend their equity capital on the purchase of CSP. Further, as hypothesized in *Hypothesis 2*, the results indicate that asset endowment has a strong and significant effect on the decision to use CSP. It suggests that farmers better off are indeed more likely to use CSP as compared with their counterparts.

Table 3 also shows that, among the conditioning variables, the size of the respondent's household, owning a mobile phone, the distance to produce market, marketing risks, and household food insecurity, and a farmer's perceptions of the tolerance of quality seed towards pests and of their perception of the taste of potato from the CSP varieties all reduce the likelihood of a farmer deciding to use quality seed.

Table 3. Factors influencing the decision to use and the extent of use of certified seed potato (CSP).

	Probit Model $^{\xi}$		Poisson Model $^{\xi}$		Tobit Model	
Variable	**Coeff**	***p*-Value**	**Coeff**	***p*-Value**	**Coeff**	***p*-Value**
gender	0.129	0.470	0.225	0.342	0.531	0.053
hhdsize	−0.101	0.111	−0.107	0.141	−0.120	0.330
lnage	−0.285	0.480	−0.243	0.650	−0.574	0.388
phone	−0.670	0.017 **	−0.699	0.052 *	−1.065	0.029 **
experience	0.011	0.284	0.006	0.638	0.012	0.443
memgrp	0.711	0.007 ***	0.713	0.010 ***	0.832	0.014 **
lnland	0.079	0.002 ***	0.071	0.000 ***	0.187	0.001 ***
lndistmkt	−0.188	0.087 *	−0.155	0.173	−0.249	0.161
lndistkisima	−0.128	0.083 *	−0.105	0.335	−0.249	0.041 **
indistagric	0.092	0.337	0.026	0.831	−0.123	0.434
lnasset	0.279	0.000 ***	0.333	0.000 ***	0.536	0.001 ***
pest	−0.028	0.003 ***	−0.011	0.060 *	−0.020	0.000 ***
blight	−0.003	0.814	−0.002	0.916	0.027	0.775
taste	−0.091	0.023 **	−0.075	0.000 ***	−0.081	0.000 ***
market	0.159	0.092 *	0.027	0.026 **	0.173	0.318
risk	−0.461	0.035 **	−0.499	0.068 *	−0.777	0.025 **
foodsec	−0.039	0.044 **	−0.029	0.367	−0.038	0.247
constant	−1.766	0.295	−3.735	0.092	−3.975	0.162
	F = 3.84	0.005	F = 10.08	0.000	F = 2.31	0.047

N = 408; The asterisks ***, **, * indicate significance at 1%, 5%, 10% respectively; ξ = model estimated using the survey regression technique.

The negative relationship between household size and the decision to use CSP could be because larger households have higher and more urgent household cash expenses, which reduce the amount of disposable income available for spending on more quality seed. The findings relating to perceptions about tastes, and pest and disease tolerance, both of which are included in the model to capture farmers' varietal and trait preferences, are contrary to our expectations. Nonetheless, the negative relationship between perceptions about tastes and the decision to use quality seed could arise when farmers perceive the other kinds of seed potato to be superior to the CSP varieties in certain preferred attributes, especially taste. Results also show that the perception of the market for potato, in general, as being risky is negatively associated with the decision to use quality seed.

The second and third columns of Table 3 also show that land ownership, membership to farmer organizations, and the perception that quality seed has a good market all increase the likelihood of a farmer's decision to use such seed. These findings indicate that farmers who are more endowed with different kinds of capital assets are more likely to use quality seed. The finding related to the marketability of potato produced from quality seed is in line with a priori expectations, namely, that farmers will invest in an improved variety if it has a good market.

4.3. Factors Affecting the Intensity of Use of CSP

The fourth and fifth columns of Table 3 present the results of the survey Poisson regression model estimated to assess the factors that affect the number of CSP varieties planted by the farmer, once a decision to use quality seed is made. Contrary to *Hypothesis 1*, the distance to the CSP source had no effect on the expected number of CSP varieties planted. This finding is not surprising. Once a decision is made to plant CSP, farmers can plant any and all of the CSP varieties at no additional cost, albeit in small quantities, because the different varieties can be picked up in a single purchase. Results also show, contrary to *Hypothesis 3*, that household food insecurity, although affecting the decision to use CSP, has no effect on the expected number of CSP varieties a farmer decides to plant once a decision to use CSP is made. This finding therefore implies that, once the major hurdle of whether to use CSP is out of the way, the expected number of CSP varieties planted does not matter in the use of CSP. However, results show that endowment with physical assets, a proxy for wealth, has a strong and significant effect on the expected number of CSP varieties planted. This finding is also in line with a priori expectations and may be associated with the ability of the better-off (wealthier) farmers to afford the cost of CSP.

As also shown in Table 3, some of the control variables, namely, mobile phone ownership, farmers' ranking of the importance of taste and pest tolerance, as well as farmers' perception of the marketing risk, also affect the expected number of CSP varieties planted. These control variables reduce the expected number of CSP varieties planted. The finding relating to "market risk" for instance, indicates that the expected number of CSP varieties planted by a farmer who perceives the market for potato to be risky will be lower by almost 50%, all other things being equal.

Results in Column 4 and 5, however, show that, among the remaining control variables in the survey Poisson regression, the size of land owned by the farmer, membership to a farmer organization, and the perception that produce from CSP is marketable increase the expected number of quality seed varieties from Kisima Farm planted. In particular, results show that an increase in the size of land by one acre increases the expected number of CSP varieties planted by 7%, all other things being equal. This finding underscores the significance of access to land on the extent to which CSP varieties are used. This finding also relates to the fact that farmers usually plant different varieties of potato separately and hence need more land to plant more varieties. Membership to a farmer organization also has a large effect on the expected number of CSP varieties planted. Together, the results of the survey Poisson regression model indicate that, once a farmer has decided to use CSP, endowment with physical and social assets and the perception of the marketability of ware potato produced from CSP play a significant role in the decision on the number of quality seed varieties planted.

The results of the Tobit regression model, estimated to test the effects of the distance to the source of CSP, asset endowment, and household food insecurity on the total area of land planted with CSP, are presented in the last 2 columns of Table 3. As hypothesized in *Hypothesis 1* and *Hypothesis 2*, the results show that the distance to the source of CSP and asset endowment have a strong and significant effect on the total area of land planted with CSP. The former, as expected, reduces the area planted. An increase in the distance to the CSP source by one kilometer reduces the area planted by 0.08 hectares, all other things being equal. As discussed in Section 1, seed potato is bulky; hence, the longer the distance seed potato has to be hauled, the higher the cost of transportation. The combined high cost of CSP and transportation costs therefore seem to reduce the area planted with CSP. Higher endowment with physical assets, on the other hand, increases the total area of land planted with CSP. Contrary to *Hypothesis 3*, however, the results show that household food insecurity has no effect on the area planted with CSP. As in the Poisson model, this finding may be related to the fact that, once a farmer decides to use CSP, implying that they can afford it, household food insecurity is no longer relevant because such a household must have been food secure in the first place to decide to spend its equity capital on seed potato.

5. Summary, Conclusions and Implications

This study examined the determinants of use and intensity of the use of CSP by smallholder potato growers in Kenya. The study tested three hypotheses, namely, that the distance to the source of CSP (*Hypothesis 1*), endowment with physical assets (*Hypothesis 2*), and household food insecurity

(*Hypothesis 3*) affect the adoption of CSP. Two proxies were used as measures of the intensity of the use of CSP, namely, the number of individual CSP varieties planted and the total area of land under CSP.

As hypothesized, the study found that the distance to the source of CSP, endowment with physical assets, and household food insecurity affect the likelihood that a farmer will decide to use CSP. Both the distance to the source of CSP and household food insecurity reduce the likelihood of the use of CSP, while asset endowment increases it. The distance to the source of CSP also affects the area planted but has no effect on the number of CSP varieties planted. On the other hand, household food insecurity has no effect on either proxies of intensity of the use of CSP. Contrary to hypotheses 1 and 3, asset endowment strongly increases the likelihood of using CSP as well as the expected number of varieties used and land planted with CSP. Several other conditioning variables also affect the decision to use CSP and the intensity of use.

The study therefore concludes that the distance to the CSP source, and hence the high transaction cost, has an effect only on the decision to use CSP and the quantity used but not the number of CSP varieties. These results corroborate findings of earlier literature, which suggest that farmers who are located far away from input markets often face high transaction costs that dampen the incentive to invest in farming [38,39]. They imply that the promotion of CSP should be accompanied by strategies that help reduce the transaction costs farmers face in attempting to access CSP. Apart from stronger encouragement to farmers to participate in collective action, improvements in physical infrastructure (especially roads) and information access can also reduce these transaction costs.

This study also concludes that household food insecurity impedes the decision by farmers to use CSP. It is likely to force a household to focus on feeding its members rather than purchasing new and more expensive CSP. This finding implies the need for social support to such households. One option, just as discussed above, is the use of collective action. Such households can band together in groups and buy CSP in bulk, thus benefitting from economies of scale in the form of price discounts and lower per-unit transportation and transaction costs.

The study further concludes that poor households are less likely to benefit from the use of CSP. This implies the need to support such households. This can be done through the use of smart subsidies. An example of such subsidies already piloted in Kenya for certified grain seeds and fertilizers is the national accelerated agricultural input access program (NAAIAP) implemented by the Kenya government [39,40]. Expansion of the basket of inputs that currently constitute the subsidy to include seed potato in the potato growing areas of Kenya can help reach poor potato farmers with more productive CSP. Indeed, we recommend the inclusion of other "food crop seeds" in the scaling out of the program to avoid "maize-centric" production system that overlies the promotion of the production of maize at the expense of other food crops [40].

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