Adoption of improved potato varieties in Ethiopia: The role of agricultural knowledge and innovation system and smallholder farmers' quality assessment

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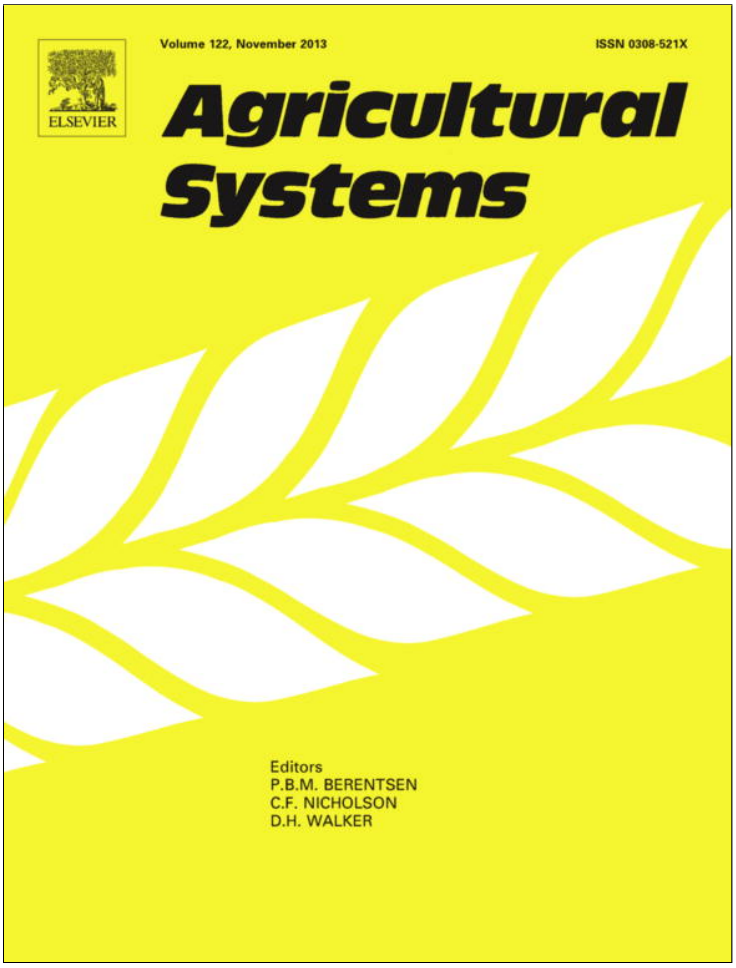
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Adoption of improved potato varieties in Ethiopia: The role of agricultural knowledge and innovation system and smallholder farmers' quality assessment

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ABSTRACT

Although potato is considered to be one of the strategic crops for ensuring food security in Ethiopia, the adoption of high yielding and disease tolerant improved potato varieties is low. Common explanations include farmers' attitudes to risk and socio-cultural factors. We develop a system perspective that explores farmers' decisions about adopting improved varieties (IVs) in relation to (1) their engagement with the agricultural knowledge and innovation system (AKIS) and (2) their preferences for local varieties (LVs). On the basis of original data from 346 ware Ethiopian potato farmers we show that the frequency of use of technical assistance from NGOs and access to credit positively affect the adoption of IVs while the use of the main buyer as a source of advice negatively affects IV adoption. We found that farmers have a preference for LVs because of the perceived easier crop management and better stew quality attributes. Yield, disease resistance, and maturity period are less important attributes. Higher education of the household head and the presence of a radio and/or television also have a positive effect on adoption. As to the scale of adoption, we found that only the percentage of owned land, tuber size (of ware potatoes), access to credit, stew quality, and presence of a mobile phone have an impact on ware potato farmers' decision on the amount of land to be used for growing IVs. These results imply that improved production-related quality attributes may not be enough to induce ware potato farmers to adopt new varieties. LVs with relatively low scores on production-related criteria continue to be appreciated by farmers due to demands from their customers. We recommend putting more emphasis on market-related quality attributes in new variety development.

1. Introduction

Genetically improved varieties of staple crops can play an important role in ensuring the availability of sufficient food for a growing population (Rizvi et al., 2012; Serageldin, 1999). Potato is considered to be one of the main staple crops for ensuring food security (Knapp, 2008; Struik and Wiersema, 1999), providing more calories, vitamins and nutrients per unit area than any other staple crop (Sen et al., 2010). Improved varieties (IVs) have better yields (Chakraborty et al., 2000) and are more resistant to late blight (Song et al., 2003), virus and bacterial wilt (Thiele, 1999). Potato can play a significant role in ensuring access to food at the household level and can also generate income for smallholders, thereby contributing to the economic sustainability of agricultural systems in developing countries (Thompson and Scoones, 2009). In Ethiopia, potato has increasingly become a source of cash income for farmers, and retains its importance for household consumption (Gildemacher et al., 2009a, 2009b; Mulatu et al., 2005).

Despite the benefits of IVs (enhanced yield and disease resistance), Ethiopian farmers are often reluctant to grow them. This is despite the efforts of the Ethiopian Institute of Agricultural Research (EIAR) which, with support from the International Potato Center (CIP), has distributed 18 IVs in the last two decades in an attempt to improve the performance of the potato sector (Gebremedhin et al., 2008). However, the rate of adoption of these IVs by ware potato farmers (farmers who grow potato for consumption rather than to be used as seed) has been very low. Data from a national representative survey (collected from over 8000 households) revealed that only 0.5% of the households used improved seed potatoes (ESCS, 2005).

The EIAR recognizes the problem with low adoption rates by ware potato farmers, although the causes have not been fully investigated. For example, the EIAR mentions a shortage of improved seeds and poor supply systems as the main limiting factors (Gebremedhin et al., 2008). This assumes that adoption is

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low because of supply problems and potential adopters not having access to IVs. However, this view is not supported by the empirical evidence. Abebe et al. (2010) found that IVs released in recent years were widely grown by seed potato farmers in the highlands, with the main buyers being government agencies and NGOs. Given this, we hypothesize that the problem of low adoption of IVs by ware potato growers cannot be solely explained by the unavailability of quality certified seed or the lack of a formal seed supply system.

One possibility is that the IVs developed by the Ethiopian agricultural knowledge and innovation system (AKIS) lack the attributes desired by farmers. They may prefer local varieties (LVs) and assess these as having better characteristics than the IVs. The development of varieties that do not meet farmers' preferences has been attributed to the linear character of AKIS (Thompson and Scoones, 2009). One response to this has been the proposal to develop participatory research and development systems, which put farmers at the center of the innovation process (Bishaw and Turner, 2008). The participatory approach places a high value on local knowledge and seeks cooperation between farmers and researchers when designing new technologies or adapting existing ones to local circumstances (Ceccarelli and Grando, 2007; Sperling et al., 2001).

Another reason for low adoption rates could be low information exchange between AKIS and farmers (Koundouri et al., 2006; Rizvi et al., 2012; Saha et al., 1994). An effective extension system builds farmers' capacity by giving them access to information that can reduce uncertainty about the likely outcomes of a new technology (Feder et al., 1985). When research, extension, and agricultural education operate as stand-alone institutions, farmers may have difficulties in understanding and appreciating the characteristics of new varieties (Rivera et al., 2005). In other words, uncertainty about expected outcomes of IVs may be a reason why farmers continue growing LVs, the strengths and weaknesses (both in production and marketing) of which they are already familiar with.

Farmer and farm characteristics have been used to explain farmers' low receptiveness to technological change and innovation. Such factors have included risk-aversion (Abadi Ghadim et al., 2005; Feder et al., 1985; Feder and Umali, 1993; Just and Zilberman, 1983), wealth or household income (Sall et al., 2000) and socio-cultural resistance (Drechsel et al., 2005; Moser and Barrett, 2003). However, such studies often implicitly assume that the technology to be adopted is suitable (Adesina and Baidu-Forson, 1995), yet it is often difficult to evaluate the advantages and disadvantages of a new technology, such as a new crop variety. Lancaster (1966) noted that any product possesses multiple attributes, and that utility is provided by individual attributes. For example, a new potato variety can be seen as a new technology that delivers utility in terms of both production (e.g., disease resistance and yield) and consumption (e.g., cooking quality, stew quality, tuber size, and tuber shape). The decision to adopt IVs is not only determined by the farmer's risk attitude but also by the farmer's preference for different product attributes. Even when IVs have better production-related attributes, farmers may continue growing LVs that possess the preferred consumption or market related attributes.

Developing these arguments, this paper seeks to make several contributions to the literature on the adoption of improved crop varieties. The study focuses on ware potato farmers producing for the market, not on seed potato growers or farmers growing for self-consumption. Seed potato supply systems have received much academic attention in recent years (e.g., Abebe et al., 2013; Gildemacher et al., 2009a, 2009b, 2011; Hirpa et al., 2010, 2012; Mulatu et al., 2005). They have also been the focus of much work by the International Potato Center (CIP). In East Africa, CIP has involved farmers in Integrated Pest Management (IPM) experiments and variety selection of sweet potato (Abidin, 2004; Smit and Odongo, 1997; Thiele et al., 2001). In Ethiopia, CIP has used participatory research approaches such as farmer fields schools (FFSs) and farmer research groups (FRGs) among seed potato growers in the highland areas (Ortiz et al., 2011). However, not much attention has been paid to the links between seed potato growers and ware potato farmers. We argue that a potato innovation system will only be successful when ware potato farmers adopt IVs.

Second, we apply a system perspective in studying the factors that determine adoption, including both the influence of the AKIS and other value chain actors. Recently, Ortiz et al. (2013) studied potato innovation systems in Bolivia, Ethiopia, Peru and Uganda, focusing on the roles of different institutions involved in the potato innovation system. They found that interactions among stakeholders improved the working of the potato innovation system. Their study focused on analyzing the processes of innovation. By contrast we analyze the performance of the Ethiopian AKIS from the perspective of adoption rates. Our study complements the work of Ortiz et al. (2013) and provides evidence on the determinants of adoption of IVs in Ethiopia. While research, extension, cooperatives, and NGOs can all play an important role in the development and diffusion of new varieties (Ortiz et al., 2013), buyers' preferences also play a crucial role in farmers' decisions to choose particular varieties (Asfaw et al., 2012). This influence is often not taken into account in adoption studies.

Third, little attention has been paid to the impact of farmers' assessment of existing varieties on the probability of their adopting new ones. We analyze the relationship between farmers' assessments of the production and market-related attributes of LVs and the probability of them adopting IVs. To our knowledge, this issue has not been explored before. For instance, Sall et al. (2000) and Adesina and Baidu-Forson (1995) studied the effect of farmers' perceptions about the characteristics of new technologies on adoption but did not include the existing ones. We examine the likelihood of farmers adopting IVs by looking at their assessment of the attributes of LVs.

Fourth, while potato is an increasingly important food crop in developing countries, it has received little attention in the adoption literature, compared to other staple crops, such as rice, maize, and sorghum. As there are important differences between potato and cereal crops (Ortiz et al., 2013), the findings from the existing adoption literature may not be sufficient to understand farmers' decisions about whether or not to grow improved potato varieties.

The aim of this paper is to provide insights into the determinants of adoption of IVs by analyzing farmers' assessment of (a) the operation of the Ethiopian AKIS and (b) the attributes of LVs. In respect of AKIS, we are particularly interested in how farmers experience and assess the technical assistance provided by extension services, research institutes, NGOs, and cooperatives. We also analyze the impact of farmers using their main buyer(s) as a source of advice.

Adoption decisions can be analyzed using static or dynamic models. Static models only explain adoption decisions at a particular point in time. Dynamic models are considered ideal for studying adoption decisions over several periods (Koundouri et al., 2006), but they require panel data, which is difficult to obtain. Our empirical approach, following Besley and Case (1993), uses a model that measures the persistence of adoption over a period of five years (although this does not necessary reflect the rate of seed renewal in Ethiopia). Studies have shown that cross-sectional data can be safely used to study adoption decisions when the adoption process moves toward its completion; i.e., when the new technology has already been used for sometime (Besley and Case, 1993; Cameron, 1999). Our study benefits from the fact that the IVs were released more than five years before this study was conducted.

Nevertheless, we are careful with the interpretation of the results, as the parameter estimates do not necessarily reflect causal relationships due to the possible omission of variables (bias) and reverse causality (Cameron, 1999; van Rijn et al., 2012).

The remainder of the paper is structured as follows. Section 2 explains the conceptual model. Section 3 presents the methods employed. This is followed by the results and discussion in Sections 4 and 5. Section 6 provides the conclusions.

2. Conceptual model: factors influencing adoption

2.1. The impact of AKIS on the adoption of improved varieties

According to Rivera et al. (2005), an AKIS encompasses the entire system of agencies and institutions that provide rural people with the knowledge and information necessary for innovation in their diversified livelihoods. The AKIS literature distinguishes two models for the development and diffusion of new technologies – the linear model and systemic model. The linear model assumes farmers to be passive recipients of new technologies. Innovations are seen as originating from international research centers, which are then passed down to national research centers, extension agencies and, finally, to farmers (Biggs, 1990; Rogers, 1995). The publicly-sponsored AKIS often generates generic technologies that are not aligned with farmers' needs (Rivera et al., 2005). As such it has been argued that an AKIS organized along these lines has little influence on farmers' decisions (Pascucci and de-Magistris, 2011). By contrast, the systemic view on AKIS acknowledges that the agricultural innovation system contains different actors pursuing diverse objectives (Rivera et al., 2005) and recognizes that innovation processes are non-linear and context specific (Klerkx and Leeuwis, 2008; Sumberg, 2005). The systemic model emphasizes decentralized decision-making, the participation of private actors, institutional pluralism and demand-driven research and extension (Pascucci and de-Magistris, 2011; Rivera, 2008; Rivera et al., 2005). While the linear model of AKIS assumes that farmers are mere recipients of agricultural innovations, the systemic view considers them as part of the innovation process, even as originators of agricultural technologies (Rivera et al., 2005). The systemic model is assumed to lead to higher adoption rates.

In Ethiopia, the AKIS has three main components – the Ethiopian Institute of Agricultural Research (EIAR), the Regional Agricultural Research Institutes (RARIs), and Higher Learning Institutes (HLIs). The EIAR is responsible for developing improved agricultural technologies, coordinating agricultural research, and building the capacity of researchers at the national level: the RARIs and HLIs are in charge of research and education at regional level. There are about 55 research centers and sites spread across the different agro-ecological zones of Ethiopia. Although over 2% of GDP is spent on agricultural extension every year (Spielman et al., 2010), technology adoption has been slow, crop yields have remained low, and no sustained breakthroughs have been seen in regions where research has been carried out (Abate et al., 2011).

Several factors have been identified as potential causes for the poor performance of the Ethiopian AKIS. First, the research priorities have largely been driven by concerns about food security (Spielman et al., 2011). Hence, production-related attributes, such as yield, have been given high priority when developing new varieties (Gebremedhin et al., 2008). However, high yielding varieties may not have a high market demand. Second, there is a lack of coordination among the formal institutes engaged in R&D activities as well as weak linkages between these institutes and farmers and private sector firms (Spielman et al., 2011). Third, the extension service in Ethiopia often pays little attention to farmers' experiences and knowledge and extension workers often lack up-to-date knowledge and skills (Belay and Abebaw, 2004).

We expect that adoption of IVs is affected by farmers' assessment of the characteristics of the AKIS. In our conceptual model, we include variables that express this; including the frequency of use of technical assistance from extension services, research institutes, cooperatives, or NGOs; advice from main buyer(s); and time spent in a farmer training center (FTC). FTCs provide education (market information) and advisory services (e.g. on land and natural resource management) and promote the use of improved technologies (Tefera et al., 2011). FTCs were introduced in 2009 by the Ethiopian government as part of its agricultural-led development strategy.

If the innovation development and diffusion system works effectively, we would expect a positive relationship between the assessment of AKIS and the probability of adoption (Rivera et al., 2005). The variable 'Main buyer as a source of advice' is used as a proxy in assessing whether downstream actors in the potato value chain are part of the AKIS (as proposed by the systemic model on innovation). To control for capital constraints, we also include access to credit in our model.

2.2. Farmers' quality assessment of LVs and the adoption of IVs

Quality is an elusive concept (Luning et al., 2002); it is difficult to measure as it depends on many factors including the nature of the product, the user of the product and the market situation (Sloof et al., 1996). Defining quality from a value chain perspective is even more problematic as different chain actors may assess quality differently based on the attributes of the product which they find more important (Table 1).

Because farmers assess varieties both on their agronomic characteristics and on their marketability, we distinguish between production-related and market-related attributes. Quality attributes such as yield, disease tolerance, maturity period, drought resistance and intensity of crop management are production-related, and determine the attractiveness of a variety from a farming perspective. Quality attributes such as tuber size, stew quality, cooking quality and shape are market-related, as these attributes determine the attractiveness of a variety from the customers' point of view. Stew quality refers to the taste of ware potatoes when they are cooked together with vegetables in liquid (i.e. in a stew). Cooking quality refers to the taste of the potato when boiled by itself. We expect that if ware potato farmers have a positive assessment about important production and market related quality attributes of the LVs then, ceteris paribus, the probability of them adopting IVs is low. Thus, our empirical strategy is to analyze the effect of farmers' assessments of the characteristics of existing varieties on their decision to adopt a new variety.

We also expect several household and farm characteristics to influence the adoption of IVs; these variables are commonly included in adoption studies (Abdulai and Huffman, 2005; Adhiguru et al., 2009; Floyd et al., 2003; Mariano et al., 2012; Schipmann and Qaim, 2010; Thangata and Alavalapati, 2003).

Fig. 1 shows the conceptual model. We assume that adoption decisions are conditioned by the farmers' assessment of AKIS, the

Table 1
Interpretation of quality by various chain actors. *Source*: Ruben et al. (2007, p. 30).

Actor	Quality aspects
Breeder	Vitality of seed, yield
Grower	Yield, uniformity, disease resistance
Distributor	Shelf life, availability, sensitivity to damage
Retailer	Shelf life, diversity, exterior, little waste
Consumer	Taste, healthiness, perishability, convenience, constant quality

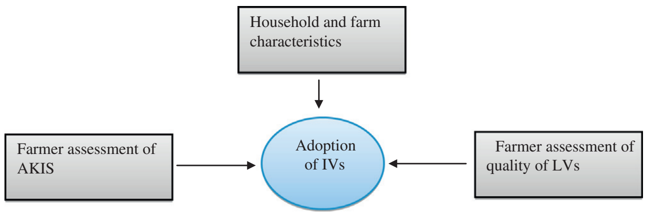

Fig. 1. Conceptual model.

farmers' evaluation of the quality of LVs and by household and farm characteristics.

3. Methods

3.1. Data

We collected data from the Ethiopian potato value chain, with a particular focus on the Upper Rift Valley region. Although potato is produced in different parts of the country, our study focuses on this region for two main reasons. First, the Upper Rift Valley region is the main source of ware potatoes for the major cities of Ethiopia. For instance, the Shashemene spot market, in the center of our study region, is the main trade hub for ware potatoes in Ethiopia (Emana and Nigussie, 2011; Tefera et al., 2011). Second, to analyze farmers' perceptions about the quality of LVs it is necessary that the farmers in the survey have the same understanding of the LVs. In Ethiopia, variety names lack standardization and often have names from local languages (Cavatassi et al., 2011). Thus, by focusing on one region we avoid problems arising from any confusion of variety names.

Data were collected from 346 potato farmers who were randomly selected from the land ownership register obtained from the Office of Agriculture and Rural Development. The survey was administered in person by five trained interviewers. Supervision and quality checks were made by the principal investigator. Table 2 describes the main variables.

Panel A presents summary statistics for the adoption data. The first adoption variable refers to the presence of at least one IV on the farm. Thus, we record the presence of IVs if the farmer had grown at least one IV during the 2006–2010 period. On average 27% of farmers in the sample adopted at least one IV during this period. Since this might be considered a shallow measure of adoption, a second variable, persistence of adoption, is also introduced; this refers to the number of years that a farmer has grown IVs. If a farmer switched from one IV to another, this is recorded in the persistence of adoption model but not in the presence of adoption model. Finally, we introduce variables related to the intensity of adoption. Firstly, we use the percentage of farm land cultivated with IVs in the production year 2010. We also calculate the intensity of adopting the IVs as a percentage of total area used for growing potato. Our results show that adopters allocated an average of 8% of their total agricultural land, and 20% of the land dedicated to potato production, to growing IVs.

Panel B summarizes the variables related to the role of AKIS. A number of variables ('Frequency of use of technical assistance from extension services', 'Frequency of use of technical assistance from research institutes', 'Frequency of use of technical assistance from cooperatives', 'Frequency of use of technical assistance from NGOs', and 'Main buyer as a source of advice') are measured by the recorded frequency of technical assistance or advice received by the ware potato farmer over the last two years. These are measured on a four point scale; 1 implies that the respondent has not received any technical assistance or advice and 4 implies that the respondent has frequently received technical assistance or advice in the last two years (at least once every three months). This technical assistance is not necessarily related to potato production, but could cover any aspect of farm management. The variable 'Number of days spent in farmer training centers' is measured by the number of times (days) the respondent has attended trainings organized in farmer training centers in the last year. The variable 'Access to credit' is measured as a dummy variable; 1 implies that the respondent has received credit at least once in the last two years, and 0 implies otherwise. All the variables refer to the year 2010.

Technical assistance variables could potentially be endogenous, particularly due to possible reverse causality or simultaneity, meaning that the adoption of IVs could increase the frequency of technical assistance. However, in our case, usage of technical services is likely to be exogenous for at least two reasons. Firstly, technical assistance covers general rather than specialized services. In other words, farmers are exposed to different technical services dealing with the farm management in general and not related to specific crops or technologies. Secondly, technical assistance or extension services are given in a 'top-down' fashion, and each farmer has an equal chance of receiving technical assistance. This means that farmers cannot access the services 'on demand'. Thus a farmer who has adopted an IV is not likely to receive a higher priority for technical assistance than one who did not.

Panel C shows the variables related to quality assessment for the LVs. Firstly, we had to identify the main potato varieties in the study area. The identification was based on variety names given by the surveyed farmers, and was triangulated with information obtained from agricultural agents and focus group discussions. We documented four LVs (Agazer (AZ), Nechi Abeba (NA), Key Dinch (KD), and Key Abeba (KA)), and three IVs (Gudane (GD), Jalene (JL), and Bule (BL). Secondly, because different supply chain actors define quality differently, we systematically analyzed quality using two categories of quality attributes: production-related (or agronomic) and market-related (or marketability). Attributes such as yield, disease tolerance, maturity period, drought resistance, and management intensity are production-related, while tuber size, stew quality, and shape are market-related. Because our objective is to analyze the impact of farmers' perceptions of the quality attributes of LVs on their adoption of IVs, the quality assessment variables relate only to the LVs. The production-related quality attributes of LVs are measured through the variables 'Disease resistance', 'Drought resistance', 'Intensity of crop management', 'Maturity period', and 'Yield'. The first three variables are measured using a five-point scale; 1 implies that the LV scores very low on a desirable quality attribute, and 5 implies the LV scores very high on a desirable quality attribute. 'Maturity period' was measured in days and 'Yield' was measured in quantity produced (100 kg/ha) in the last year, The market-related quality attributes of LVs were measured by the variables 'Tuber size', 'Stew quality', and 'Tuber shape'. 'Tuber size' is measured in a five-point scale; 1 implies that the LV has a very small tuber size (approximately less than 30 mm in diameter), and 5 implies that the LV has a very large tuber size (approximately larger than 57 mm in diameter). Stew quality is also measured on a five-point scale; 1 implies that the LV has a very low stew quality, and 5 implies that the LV has a very high stew quality. 'Tuber shape' is measured using a three-point scale; 1 implies that the LV is fully round, and 3 implies the LV fully oval.

Finally, Panel D presents household and farm related variables, which include age; gender; farmer education; family size; number of livestock units; land ownership; the presence of a motorbike, car, and/or truck; and of a mobile phone radio and television.

We also present an overview of the persistence of adoption for IVs (Fig. 2). 73% of ware potato farmers did not adopt any of the IVs during the period 2006–2010. Most of the adopters tried the IVs only once.

Table 2
Descriptive statistics.

Variable	Type	Obs	Mean	Std. dev.	Min	Max
Panel A: Adoption variables						
Presence of adoption	Dummy	346	0.28	0.45	0	1
Years of adoption	Continuous	346	0.48	0.86	0	5
Percentage of land with IVs on total farm land	Percentage	344	2.1	6.3	0	6.3
Percentage of land with IVs on potato farm land	Percentage	345	5.1	14.2	0	100
Panel B: Assessment of AKIS						
Frequency of use of technical assistance from extension agents	Scale; 1 = never, 4 = very often	346	2.82	0.92	1	4
Frequency of use of technical assistance from research institutes	Scale; 1 = never, 4 = very often	346	2.41	0.70	1	4
Frequency of use of technical assistance from cooperatives	Scale; 1 = never, 4 = very often	346	2.315	0.54	1	4
Frequency of use of technical assistance from NGOs	Scale; 1 = never, 4 = very often	346	2.214	0.48	1	4
Days spent in farmer training centers	Continuous (in days)	346	6	11	0	90
Main buyer as a source of advice	Scale; 1 = never, 4 = very often	346	2.15	0.56	1	4
Access to credit	Dummy	346	0.09	0.28	0	1
Panel C: Quality assessment of LVs						
Yield	Continuous (100 kg/0.25 ha)	337	27.82	10.76	5	90
Disease resistance	Scale; 1 = very low, 5 = very high	346	3.15	0.82	1	5
Drought resistance	Scale; 1 = very low, 5 = very high	346	3.50	0.87	1	5
Intensity of crop management	Scale; 1 = very low, 5 = very high	346	3.90	0.75	1	5
Maturity period	Continuous (in days)	344	89	11	60	140
Tuber size	Scale; 1 = very small, 5 = very large	346	3.23	0.57	2	5
Tuber shape	Categorical (1 = full, round; 2 = semi-oval; 3 = oval)	346	1.92	0.32	1	3
Stew quality	Scale; 1 = very low, 5 = very high	346	3.87	0.71	1	5
Panel D: Household and farm controls						
Age of the respondent	Continuous (in years)	346	36.80	10.55	20	75
Farmer being a male	Dummy (1 = male)	346	0.96	0.20	0	1
Farmer years of education	Continuous (in years)	346	5.65	3.54	0	15
Family size	Continuous (in members)	346	9.59	5.17	1	39
Presence of a motorbike, car and/or a truck	Dummy (1 = presence)	346	0.03	0.19	0	2
Presence of a mobile phone	Dummy (1 = presence)	346	0.67	0.47	0	1
Presence of a radio	Dummy (1 = presence)	346	0.65	0.48	0	1
Presence of a television	Dummy (1 = presence)	346	0.10	0.29	0	1
Percentage own land (of total land used)	Percentage	344	73.1	25.6	0	100
Number of livestock units	Continuous (in TLU)[a]	346	9.0	17.9	0	274

[a] Tropical Livestock Unit (TLU) is used as a common unit to describe livestock numbers of various species as a single figure that expresses the total amount of livestock present. Accordingly oxen/cow = 1 TLU; calf = 0.25 TLU; heifer = 0.75 TLU; sheep/goat = 0.13 TLU; young sheep/goat = 0.06 TLU; donkey = 0.7 TLU.

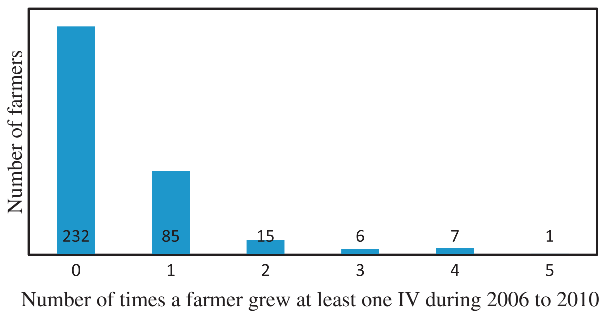

Fig. 2. Persistence of adoption for the improved varieties for the period between 2006 and 2010.

We summarize the results of the different models in Tables 3–5. Estimations were computed using Stata 12.0 software, and are reported with robust standard errors for a potential problem of heteroscedasticity.

3.2. Empirical model

Having described the variables and our data, we now turn to analyze the determinants of ware potato farmers' decision to adopt and, in case of adoption, the intensity with which these farmers adopt IVs. In our empirical model, we consider the correlation between different measures of adoption and variables related to the role of AKIS and farmers' quality assessment as follows:

$$T_i = \alpha + \beta_1 A_i + \beta_2 Q_i + \delta C_i + \varepsilon_i,$$

where T_i refers to technology adoption variables for farmer i, where $i = 1 \ldots 346$. Technology adoption variables include the presence of IVs, total number of years IVs have been used, the percentage of total farm land cultivated with IVs in 2010, and percentage of land dedicated to potato cultivated with IVs in 2010. A_i refers to AKIS variables; Q_i refers to the quality assessment variables for LVs; and C_i is a vector of control variables.

Probit or logit models have often been proposed to analyze adoption (Abadi Ghadim et al., 2005; Moser and Barrett, 2006). The Probit model takes a value of 1 for the presence of adoption and 0 for its absence. A lack of panel data has often been a problem in adoption studies although some studies, such as those by Cameron (1999) and Conley and Christopher (2001) have managed to use panel data. A partial solution to this limitation is to use recall data on each farmer's adoption history (Besley and Case, 1993; Moser and Barrett, 2006). Hence, in modeling the persistence of adoption, we use the recall technique to analyze the determinants of adoption. The Ordered Probit model takes a value of 0, 1, 2, 3, 4, or 5, depending on the number of years a farmer had grown IVs in the 2006–2010 period. To measure the intensity of adoption, we use the treatment effect (Heckman sample selection) model. The treatment effect model is used in our study to correct sample selection biases. Such a bias may arise in our data because the observations in the intensity of adoption model are only limited to those farmers who adopted the IVs (see Section 4.3).

4. Results

4.1. Presence of adoption

Table 3 shows that frequency of use of technical assistance from NGOs, use of main buyer as a source of advice, and access to credit are significant determinants of adoption of IVs. Of the quality

Table 3
Parametric estimation of the presence of adoption for growing at least one IV between 2006 and 2010.

Variables	Probit model	
	Coef.	Robust std. err.
Frequency of use of technical assistance from extension agents	−0.004	0.110
Frequency of use of technical assistance from research institutes	0.064	0.117
Frequency of use of technical assistance from cooperatives	0.001	0.169
Frequency of use of technical assistance from NGOs	0.568	0.272**
Days spent in FTC	0.013	0.008
Main buyer as a source of advice	−0.563	0.170***
Access to credit	0.842	0.257***
Yield of LVs	−0.012	0.009
Disease resistance of LVs	0.012	0.142
Drought resistance of LVs	−0.213	0.126*
Intensity of crop management of LVs	−0.369	0.126***
Maturity period of LVs	0.005	0.009
Tuber size of LVs	−0.098	0.181
Tuber shape of LVs – full round	−0.467	0.489
Stew quality of LVs	−0.250	0.137*
Age	0.011	0.010
Farmer being a male	0.736	0.442*
Farmers years of education	0.079	0.029***
Family size	0.039	0.023*
Presence of a motorbike, car and/or a truck	−0.429	0.567
Presence of a mobile phone	0.109	0.225
Presence of a radio	0.481	0.206**
Presence of a television	0.748	0.292***
Percentage of own land	−0.002	0.004
Number of livestock units (TLU)	−0.032	0.016**
Constant	0.211	1.317
N	334	
R^2	0.281	

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

assessment variables, crop management intensity, drought resistance, and stew quality are significant. It is important to remember that the quality assessment variables refer to farmers' perception of the quality of LVs. Thus, a negative coefficient for any of these variables means that ware potato farmers value more the quality attributes of LVs, which implies a low probability of them adopting IVs. Years of education, the presence of a television or radio, the number of livestock units, family size, and the farmer being a male, all significantly affect the probability of adoption. The presence of a radio or television may also indicate the farm household's level of wealth. Wealthier farmers are possibly more likely to adopt as they can afford to buy IVs.

The frequency of use of technical assistance from NGOs was expected to be significantly related, as some NGOs have been actively involved in promoting IVs. Controlling other variables at mean values, the results show that the frequency of technical assistance from NGOs and access to credit are positively correlated with adoption. One interesting result is the relationship between the use of main buyer as a source of advice and the probability of adoption. Farmers who use their main buyer as a source of advice have a low chance of adopting IVs. The frequency of use of technical assistance from extension services, research institutes, and farmers' cooperatives do not have a significant relationship with farmers' adoption decisions.

The results show that crop management intensity is highly and negatively correlated to the probability of adoption; i.e., farmers perceive that LVs require less intensive crop management than IVs. This is expected, as IVs usually involve adopting new agronomic practices. For example, the two IVs Jalene and Gudane tend to have larger tuber size, and additional crop management may be necessary to control tuber size. Drought resistance is also negatively correlated to the probability of adoption. Rainfall in the Rift Valley region is often unreliable and farmers may perceive LVs as being better adapted to this situation than new varieties. Farmers' assessments of the yield, disease resistance, and maturity period of the LVs do not have a significant relation to adoption decision. This is contrary to our expectations, as LVs are often considered inferior in terms of yield and disease resistance.

The results show that market-related attributes are more important factors than yield, disease resistance, and maturity period. Stew quality is significantly and negatively correlated to farmers' adoption decisions. We expected stew quality to be relevant because ware potato is most commonly consumed in the form of stews. This result is consistent with estimates of 'Main buyer as a source of advice'. However, there is no significant association between farmers' assessment of tuber size and shape and the likelihood of adoption.

In terms of the control variables, we found that education and the presence of a radio or television have a significant positive relationship with the presence of adoption, although age has no relationship. The positive contribution of education was expected, as famers with more years in school are likely to be more able to process information. The household head being male also positively contributes to the adoption decision. The presence of a radio or television was also expected to be positively correlated to the adoption decision, since access to wider information helps to broaden farmers' understandings of new technologies. It is also interesting to note that family size has a positive impact on adoption. This could relate to IVs being higher yielding but less preferred by buyers: larger size households (with more dependents) might view IVs as a better option for household consumption. It could also be argued that a large family size means a larger labor force, which could positively affect the adoption decision. Households with a large number of livestock units are less likely to adopt IVs, possibly because adoption of IVs requires additional labor and expertise and would compete with animal production. Possession of a motor bike, car, and/or truck and percentage of owned land are not associated with adoption decisions. Two-thirds of the respondents had a mobile phone, but this has no correlation with the adoption decision. Perhaps, a mobile phone is seen more as a status symbol than as a means to access production and market-related information.

4.2. Persistence of adoption

We used an Ordered Probit (with an OLS estimation for comparison) to measure the persistence of adoption of the IVs; modeled as zero adoption, tried only once, twice, three times, four times or five times for the 2006–2010 period. Observations were recorded using a recall method.

While access to credit was important for the adoption decision it does not influence the persistence of adoption. However, the significance of technical assistance from NGOs, drought resistance, family size, and the number of livestock units increased by one level. Stew quality, which negatively affected the adoption decision (Table 3), also influences the persistence of adoption. That means that farmers' assessments about the stew quality of the LVs strongly affect the likelihood of growing IVs in subsequent seasons. Overall, the estimation of the Ordered Probit model is consistent with the OLS estimation.

4.3. Intensity of adoption

If information is available on the quantity of a dependent variable, the Tobit or Heckman sample selection (treatment effect)

Table 4
Parametric estimation for persistence of growing the IVs in the period between 2006 and 2010.

Variables	Years of adoption			
	OLS		Ordered Probit	
	Coef.	Robust std. err.	Coef.	Robust std. err.
Frequency of use of technical assistance from extension agents	−0.030	0.054	−0.057	0.090
Frequency of use of technical assistance from research institutes	−0.054	0.059	−0.090	0.106
Frequency of use of technical assistance from cooperatives	0.043	0.092	0.118	0.147
Frequency of use of technical assistance from NGOs	0.423	0.133***	0.637	0.155***
Days spent in farmer training centers	0.006	0.005	0.007	0.006
Main buyer as a source of advice	−0.255	0.059***	−0.533	0.151***
Access to credit	0.025	0.095	0.263	0.178
Yield of LVs	−0.003	0.004	−0.005	0.008
Disease resistance of LVs	−0.070	0.060	−0.059	0.124
Drought resistance of LVs	−0.079	0.057	−0.249	0.109**
Intensity of crop management of LVs	−0.234	0.079***	−0.432	0.119***
Maturity period of LVs	0.003	0.005	0.004	0.008
Tuber size of LVs	−0.092	0.104	−0.062	0.172
Tuber shape of LVs – full round	−0.093	0.130	−0.810	0.499
Stew quality of LVs	−0.145	0.062**	−0.295	0.112***
Age	0.005	0.006	0.013	0.009
Farmer being a male	0.035	0.154	0.104	0.362
Farmers years of education	0.017	0.015	0.056	0.027**
Family size	0.016	0.011	0.044	0.021**
Presence of a motorbike, car and/or a truck	0.001	0.272	0.298	0.436
Presence of a mobile phone	0.154	0.111	0.217	0.204
Presence of a radio	0.239	0.090***	0.590	0.191***
Presence of a television	0.287	0.166*	0.440	0.233*
Percentage of own land	0.002	0.002	0.001	0.004
Number of livestock units	−0.005	0.002**	−0.031	0.012***
Constant	1.354	0.574**		
N	334		334	
R^2	0.773		0.212	

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

models can better explain both the decision to adopt and the extent of adoption (Greene, 2003). However, the Tobit model is prone to two limitations. First, it imposes the effect of explanatory variables having the same effect on the decision to adopt and the extent of adoption. Second, it assumes that the same variables affect the decision to adopt and the extent of adoption. The treatment effect model overcomes both these limitations (Greene, 2003). This model involves two equations – the selection equation, which provides information on the variables that could affect the probability of adoption, and the outcome equation, which provides information on the variables that affect the extent of adoption.

To specify the treatment effect model, we run Probit and then OLS regression on positive observations (truncated regression) separately. The variables, which were included in the Probit model, are all considered in the selection equation. However, we drop the variable 'Farmer years of education', which was highly insignificant in the OLS estimation, from the outcome equation (Schipmann and Qaim, 2010).

Table 5 presents two outcome equations – the land allocated to grow the IVs as a percentage of total cultivated land and as a percentage of total land dedicated for potato. We present just one selection equation, which is similar to the Probit model presented in Table 3. However, while Table 3 shows adoption over the period 2006–2010, the selection equation in Table 5 only shows the 2010 data. Hence, the treatment effect model provides information on the variables that could affect the probability of adopting the IVs and the variables that could affect the share of land allocated to growing IVs. The test result of the treatment effect model shows that there is no sample selection bias, as the correlation coefficient between the residuals of both equations "ath (ρ)" is not significantly different from zero. We also note the similarities between the results of the selection equation and the Probit model, and between the outcome equation and the OLS regression (truncated); hence, we only present the treatment effect model when interpreting the results.

The results show that several variables ('Use of main buyer as a source of advice', 'Crop management intensity', 'Farmer's level of education' and 'Presence of a radio or television'), which are significant at 1% level in the probability of adoption, are less important influences on the extent of adoption. By contrast, the variables 'Percentage owned land' and 'Tuber size' show a significant relationship with the extent of adoption, while they are also important determinants on the probability of adoption. The extent of adoption is also influenced by access to credit, yield, and the presence of a mobile phone.

5. Discussion

The results showed that 73% of ware potato farmers did not adopt the IVs in the period 2006–2010. One reason for this may have been the lack of availability and affordability of the IVs for ware potato growers. During our survey, farmers reported that the price of IV seed potatoes was not much higher than that of LV seed potatoes. The cost of the IVs (per 100 kg) on average ranged between 8.2 and 13 USD while the cost of the most common LV, Nechi Ababa, was around 9.5 USD. Second the Ministry of Agriculture and Rural Development, EIAR, and NGOs have been actively promoting the IVs (Ortiz et al., 2013). Abebe et al. (2010) show that IV seed potatoes were being produced and put on the market by potato growers in the highlands. Thus, we conclude that low availability or a high price were not the main factors that led to low adoption.

The AKIS variables 'Frequency of use of technical assistance from NGOs', 'Main buyer as a source of advice', and 'Access to

Table 5
Parametric estimation of intensity of adoption (2010): treatment effect model.

Variable	Selection equation		Outcome equation as a percentage of			
	Decision to grow IVs		Total cultivated		Total potato land	
	Coef.	Robust std.	Coef.	Robust std.	Coef.	Robust std.
Frequency of use of technical assistance from extension agents	0.032	0.109	−0.011	0.009	0.009	0.016
Frequency of use of technical assistance from research institutes	0.084	0.114	0.024	0.014	0.053	0.040
Frequency of use of technical assistance from cooperatives	−0.130	0.166	−0.039	0.021	−0.057	0.039
Frequency of use of technical assistance from NGOs	0.447	0.251*	0.008	0.019	0.008	0.059
Days spent in farmer training centers	0.016	0.009*	−0.001	0.001	−0.001	0.001
Main buyer as a source of advice	−0.522	0.164***	0.055	0.035	0.025	0.079
Access to credit	0.791	0.291***	0.078	0.035**	0.172	0.094*
Yield of LVs	−0.015	0.010	0.003	0.002**	−0.0001	0.003
Disease resistance of LVs	0.058	0.146	0.022	0.015	−0.004	0.031
Drought resistance of LVs	−0.185	0.129	0.025	0.015	0.025	0.032
Intensity of crop management of LVs	−0.346	0.131***	0.021	0.019	0.023	0.043
Maturity period of LVs	0.008	0.009	0.0004	0.001	−0.001	0.001
Tuber size of LVs	−0.177	0.187	−0.053	0.023**	−0.106	0.046**
Tuber shape of LVs – full round	−0.381	0.488	0.022	0.071	0.061	0.139
Stew quality of LVs	−0.207	0.140	−0.005	0.013	−0.055	0.034*
Age	0.012	0.011	−0.001	0.001	−0.001	0.002
Farmer being a male	0.658	0.466	0.071	0.040*	0.081	0.119
Farmer years of education	0.089	0.031***	–	–	–	–
Family size	0.037	0.023	−0.003	0.003	−0.003	0.007
Presence of a motorbike, car and/or a truck	−0.482	0.550	−0.105	0.055*	−0.013	0.145
Presence of a mobile phone	0.116	0.234	−0.074	0.031**	−0.130	0.073*
Presence of a radio	0.565	0.217***	0.027	0.029	0.059	0.070
Presence of a television	0.870	0.299***	0.047	0.025*	−0.0406	0.0912
Percentage of own land	−0.0006	0.0039	0.0019	0.001***	0.003	0.001***
Number of livestock units	−0.024	0.014*	0.002	0.003	−0.002	0.005
Constant	−0.170	1.337	−0.266	0.147*	0.372	0.257
ath (ρ)			−0.352	0.289	−0.072	0.883
LR test of independent equations						
Chi-squared (1)			1.48			0.01
Prob > chi-square			0.224			0.935
N	334		85			85

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

credit' show a significant association with the presence and persistence of adoption. The intensity of adoption is only significantly (and positively) influenced by access to credit. This result shows a lack of coordination within the Ethiopian AKIS. While the focus of research institutes, extension agents, and NGOs is on promoting the IVs among potato farmers, the advice that farmers receive from their main buyers appears to affect the adoption of the IVs negatively, implying that potato buyers have an adverse effect on the current innovation process. This result confirms the observation by Spielman et al. (2011) that private actors are excluded from the innovation system. The different messages coming from the innovation system and from buyers seems to create a tension for ware potato farmers when making their decision about whether or not to adopt new varieties. In contrast to the findings of Adesina and Baidu-Forson (1995) and Zinnah et al. (1993), we find that the frequency of use of extension services and technical assistance from cooperatives has no significant effect on the probability of adoption. This confirms previous claims that the extension service in Ethiopia is generally ineffective in promoting the adoption of new technologies (Abate et al., 2011; Belay, 2003; Belay and Abebaw, 2004; Dadi et al., 2004), although these claims are challenged by Ortiz et al. (2013) who positively evaluated the role of extension in the Ethiopian potato innovation system. That study, however, was focused on specialized seed potato growers in the highlands, who often get technical support and seed from EIAR and CIP; therefore its findings may not necessarily apply to ware potato farmers. Other studies also found that extension has a limited role in inducing adoption of new technologies (Kafle and Shah, 2012; Mariano et al., 2012; Ransom et al., 2003; Schipmann and Qaim, 2010).

These different evaluations of the effectiveness of the extension system suggest that there are differences in the way AKIS operates in different sectors and different regions. If we use ware potato farmers' adoption decisions as a criterion to measure performance, the Ethiopian AKIS has failed to effectively promote the IVs in the study area.

The results show that crop management intensity is strongly correlated to the adoption decision. IVs may require more intensive crop management, which could adversely affect adoption decisions. Waller et al. (1998) reported that the need to shift from traditional crop management practices and to adopt integrated pest management (IPM) was a significant factor deterring potato farmers in Ohio, USA from adopting new varieties. However, crop management intensity turns out to be a less important (Table 5) influence on the extent of adoption in our study, although this may be related to the generally small area allotted for growing IVs. Drought resistance also affects the presence and persistence of adoption of new varieties. Under erratic rainfall conditions, farmers tend to rely on LVs that they know perform well in unfavorable climate conditions. Similar results have been reported for sorghum farmers (Adesina and Baidu-Forson, 1995) and rice farmers (Mariano et al., 2012). In areas where rainfall is erratic, introducing water harvesting technologies is one way to induce the adoption of new varieties (Wakeyo and Gardebroek, 2013).

Surprisingly, other production-related variables such as disease resistance, yield, and maturity period did not have a significant relationship with either the presence or the persistence of adoption. Ware potato farmers are generally convinced that all varieties are susceptible to diseases. They claimed that, although IVs appear to be less prone to diseases than LVs in the first cycle of production, they tend to degenerate faster over successive cropping cycles. However, IVs start at a much higher level of quality than LVs. Thiele (1999), who examined IV potatoes in the Andes, argued that the use of improved potato seed is profitable only when the farmer uses at least three generations of improved seeds. While we did not find a correlation between yield and the presence and persistence of adoption, in one of the outcome equations (Table 5), yield does appear to positively affect the extent of adoption. This implies that the yield attribute becomes important once farmers have made the decision to adopt the IVs. Maturity period is another factor that might affect adoption of new varieties. The IVs Jalene and Gudane take an average of 122 days to mature while the most common LV, Nechi Ababa, matures in 101 days. For farmers depending on rainfall, this difference in maturity period may not be so important. While the longer maturity period might increase the incidence of late blight and other diseases, our results showed that maturity period does not affect adoption of IVs.

Overall, ware potato farmers' assessment of the disease resistance, yield and maturity period of LVs played a limited role in their decision to adopt IVs. This does mean that these characteristics do not play an important role in farmers' choice of varieties. Rather, it shows that market-related quality attributes play a much greater role than production-related attributes when there are tradeoffs involved. Our results confirm the claim by Schipmann and Qaim (2010) that market-related quality attributes are critical factors for adoption. Ware potato farmers' assessment of the stew quality of the LVs appears to be the dominant market-related attribute affecting adoption decisions, as ware potatoes are mainly consumed in stew.

The importance of economic incentives for adoption decisions is also reported by Dadi et al. (2004) in the context of teff and wheat varieties. In our study farmers' assessment of tuber size did not have a significant effect on the probability of adoption. This is surprising because the IVs Jalene and Gudane have a relatively large tuber size, which could affect buyers' willingness to buy potato. Ware potato farmers generally associate larger tubers with a reduced stew quality. It is possible that the effect of size might also have been captured in the stew quality attribute. Nonetheless, we found tuber size negatively influenced the extent of adoption. Our explanation is that, once the decision to adopt is made, IVs are likely to be grown in a small plot and used self-consumption, while most of their potato land is allocated to grow LVs for the market. We found that education is significantly and positively correlated to the probability of adoption. This result is consistent with other studies (e.g., He et al., 2007; Mariano et al., 2012; Thangata and Alavalapati, 2003; Waller et al., 1998). Education can play a crucial role by reducing uncertainty and improving skills (Abadi Ghadim et al., 2005). Likewise, presence of a radio is a highly significant influence on the presence and persistence of adoption. This result is consistent with a study in India, where radio was reported to have increased the adoption of new potato varieties, (Adhiguru et al., 2009) but different from Ortiz et al. (2013), who reported that the presence of a radio played a limited role in the adoption of new potato varieties among farmers in Ethiopia, Peru and Uganda. Education level and the presence of a radio do not have any significant influence on the extent of adoption. By contrast, the presence of a mobile phone, which was not significant in the adoption decision, negatively affects the extent of adoption. While education and radio could allow farmers access to wider information, farmers may use a mobile phone to obtain market information from their main buyers. As discussed above, buyers generally have a negative perception of IVs, and farmers who adopted the IVs and have a mobile phone are likely to grow the IVs on a smaller plot of land than those who do not have a mobile phone.

6. Conclusions

The main aim of our study is to provide insights into the determinants of adopting improved potato varieties in Ethiopia, focusing on the role of the agricultural knowledge and innovation system and ware potato farmers' assessments of local varieties.

The findings show that frequency of use of technical assistance from NGOs, relying on the main buyer as a source of advice, and access to credit play a key role in ware potato farmers' adoption decisions. Technical assistance from NGOs and access to credit induce farmers to adopt the IVs, whereas relying on the main buyer as a source of advice has the opposite effect. Farmers' assessments of the quality attributes of the LVs also affect their adoption of IVs. While production-related attributes such as yield and disease resistance are considered highly important by the Ethiopian AKIS, ware potato farmers considered them to be of secondary importance. They consider crop management intensity and stew quality as the most important quality attributes. Among the household and farm controls, education and the presence of a radio or television affect the adoption of IVs. This finding suggests the importance of access to, and ability to process, information for adopting new varieties.

This paper makes a number of contributions to the adoption literature. First, we show that the introduction of new crop varieties involves a complex interplay between the forces of supply and demand, which involves actors from the AKIS and the market. Second, we showed that farmers' adoption decisions hinge on multiple criteria that involve trade-offs. While the suppliers of new potato varieties (the AKIS) tend to focus on agronomic characteristics, farmers also consider non-agronomic characteristics, such as stew quality and buyer preferences, in their adoption decision. Third, compared to other staple food crops, there is only limited empirical research on the adoption of new potato varieties by ware potato growers. Following Thiele (1999), we think that potato, with its agro-ecological and socio-cultural specificities, deserves more attention.

A number of policy recommendations can be drawn from this study. First, a supply chain view of quality, that is based on what farmers and buyers' most value, is needed if the adoption rate of IVs is to increase. We recommend that policymakers responsible for setting research agendas and researchers place more emphasis on the combination of agronomic and non-agronomic attributes when developing new varieties. The preferences of ware potato farmers and their customers should be included in the process of setting research priorities, which necessarily implies a more participatory approach to research. This recommendation is in line with Byerlee et al. (2007) who, in the context of new sorghum varieties, suggested a rethink of the existing innovation diffusion system in Ethiopia. A second policy recommendation relates to the importance of education and access to information, which proved to be crucial in adoption decisions. Although two-thirds of ware potato farmers in our study had a mobile phone, this did not have a significant effect on the probability of adoption. Institutions involved in the innovation process should therefore seek new ways to utilize the technology. For instance, Mittal et al. (2010) reported on the Indian AKIS using mobile phones to disseminate specific information on prices, the availability of inputs, seed quality and the adoption of modern technologies. A third recommendation focuses on the use of broadcasting media, such as radio and television. These media turned out to be important for the adoption decision, and policymakers could use the recently expanding community level radio stations to educate and promote the adoption of new agricultural technologies.

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