

Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries

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Abstract
Agricultural technologies are seen as an important route out of poverty in most of the developing countries. However the rate of adoption of these technologies has remained low in most of these countries. This study aim at shedding some light on the potential factors that influence agricultural technology adoption in developing countries. It does so by reviewing previous studies done on technology adoption. From the study technological, economic, institutional factors and human specific factors are found to be the determinants of agricultural technology adoption. The study recommend the future studies on adoption to widen the range of variables used by including perception of farmers towards new technology.
Keywords: Technology, Adoption, smallholder

Introduction

Agriculture plays an important role in economic growth, enhancing food security, poverty reduction and rural development. It is the main source of income for around 2.5 billion people in the developing world (FAO, 2003). Smallholder agriculture is identified as a vital development tool for achieving Millennium Development Goals, one of which is to halve the people suffering from extreme poverty and hunger by 2015 (World Bank, 2008). However majority of smallholder farmers relies on traditional methods of production and this has lowered the level of productivity. For instance Over 70% of the maize production in the majority of developing countries is from smallholders who use traditional methods of production (Muzari et al., 2012). These farmers generally obtain very low crop yields because the local varieties used by farmers have low potential yield, most of the maize is grown under rain-fed conditions and irrigation is used only in limited areas, little or no fertilizers are used and pest control is not adequate (Muzari et al., 2012; Shao, 1996). This has triggered much of discussion on the need to increase productivity and sustainability in agriculture globally but much less information is available on specific means to achieve this aim.

Increasing agricultural productivity is critical to meet expected rising demand and, as such, it is instructive to examine recent performance in cases of modern agricultural technologies (Challa, 2013). Agricultural technologies include all kinds of improved techniques and practices which affect the growth of agricultural output (Jain *et al.*, 2009). According to Loevinsohn *et al.* (2013) the most common areas of technology development and promotion for crops include new varieties and management regimes; soil as well as soil fertility management; weed and pest management; irrigation and water management. By virtue of improved input/output relationships, new technology tends to raise output and reduces average cost of production which in turn results in substantial gains in farm income (Challa, 2013).

Adopters of improved technologies increase their productions, leading to constant socio-economic development. Adoption of improved agricultural technologies has been associated with: higher earnings and lower poverty; improved nutritional status; lower staple food prices; increased employment opportunities as well as earnings for landless laborers (Kasirye, 2010). Adoption of improved technologies is believed to be a major factor in the success of the green revolution experienced by Asian countries (Ravallion and Chen, 2004; Kasirye, 2010).On the other hand, non-adopters can hardly maintain their marginal livelihood with socio-economic stagnation leading to deprivation (Jain *et al.*, 2009).

A new agricultural technology that enhances sustainable production of food and fiber is therefore critical for sustainable food security and economic development. This has made the dynamics of technical change in agriculture to be an area of intense research since the early part of twentieth century (Loevinsohn et al., 2013). These technologies are particularly relevant to smallholder farmers in developing countries because they are constrained in many ways, which makes them a priority for development efforts. These farmers for instance, live and farm in areas where rainfall is low and erratic, and soils tend to be infertile. In addition, infrastructure and institutions such as irrigation, input and product markets, and credit as well as extension services tend to be poorly developed (Muzari et al., 2012).

Over the years many studies have been conducted on innovation and uptake of new technologies in developing countries. In addition the process of adoption and the impact of adopting new technology on smallholder farmers have been studied. However new agricultural technologies are often adopted slowly and several aspects of adoption remain poorly understood despite being seen as an important route out of poverty in most of the developing countries (Bandiera and Rasul, 2010; Simtowe, 2011).

This paper therefore tries to review various studies done on adoption of new technology and factors that are responsible for slow rate of technology adoption.

Literature Review

Technology adoption

Various authors define technology in different ways. Loevinsohn *et al*., 2013 define technology as the means and methods of producing goods and services, including methods of organization as well as physical technique. According to these authors new technology is new to a particular place or group of farmers, or represents a new use of technology that is already in use within a particular place or amongst a group of farmers. Technology is the knowledge/information that permits some tasks to be accomplished more easily, some service to be rendered or the manufacture of a product (Lavison 2013). Technology itself is aimed at improving a given situation or changing the status quo to a more desirable level. It assists the applicant to do work easier than he would have in the absence of the technology hence it helps save time and labor (Bonabana-Wabbi 2002)

Adoption on the other hand is also defined in different ways by various authors. Loevinsohn *et al*., 2013 defines adoption as the integration of a new technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation. Citing the work of Feder, Just and Zilberman (1985), Bonabana-Wabbi defines adoption as a mental process an individual passes from first hearing about an innovation to final utilization of it. Adoption is in two categories; rate of adoption and intensity of adoption. The former is the relative speed with which farmers adopt an innovation, has as one of its pillars, the element of 'time'. On the other hand, intensity of adoption refers to the level of use of a given technology in any time period (Bonabana-Wabbi 2002).

Defining technology adoption is a complicated task since it varies with the technology being adopted. For instance the study by Doss (2003) showed that adoption of improved seed in a survey done by CIMMYT classified farmers as adopters if they were using seeds that had been recycled for several generations from hybrid ancestors. In other studies adoption was identified with following the extension service recommendations of using only new certified seed (Doss, 2003; Bisanda 1998; Ouma 2002). Therefore in defining agricultural technology adoption by the farmers, the first thing to consider is whether adoption is a discrete state with binary response variables or not (Doss, 2003). That means definition depends on the fact that the farmer is an adopter of the technologies or non-adopter taking values zero and one or the response is continuous variable (Challa, 2013). The appropriateness of each approach depends on the particular context (Doss, 2003). Many researchers use a simple dichotomous variable approach in the farmers' decisions of new technology adoption. This approach according to Jain *et al.* (2009) is necessary but not sufficient because the dichotomous response reflects the status of awareness of improved technology rather than the actual adoption. Therefore researchers should clearly state how they are defining this term (technology adoption) so that they can develop appropriate tool to measure it.

Determinants of agricultural technology adoption

There exist vast literatures on factors that determine agricultural technology adoption. According to Loevinsohn et al. (2013), farmers' decisions about whether and how to adopt new technology are conditioned by the dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances. Diffusion itself results from a series of individual decisions to begin using the new technology, decisions which are often the result of a comparison of the uncertain benefits of the new invention with the uncertain costs of adopting it (Hall and Khan, 2002). An understanding of the factors influencing this choice is essential both for economists studying the determinants of growth and for the generators and disseminators of such technologies (Hall and Khan, 2002).

Traditionally, economic analysis of technology adoption has sought to explain adoption behavior in relation to personal characteristics and endowments, imperfect information, risk, uncertainty, institutional constraints, input availability, and infrastructure (Feder et al. 1985; Koppel 1994; Foster & Rosenzweig 1996; Kohli & Singh 1997; Rogers, 2003 and Uaiene, 2009). A more recent strand of literature has included social networks and learning in the categories of factors determining adoption of technology (Uaiene, 2009). Some studies classify these factors into different categories. For example, Akudugu *et al.* (2012) grouped the determinant of agricultural technology adoption into three categories namely; economic, social and institutional factors. Kebede *et al.* (1990) as cited by Lavison (2013) broadly categorized the factors that influence adoption of technologies into Social, Economic and physical categories, McNamara, Wetzstein and Douce (1991) categorized the factors into, farmer characteristics, farm structure, institutional characteristics and managerial structure, Nowak (1987) grouped them into informational, economic and ecological, while Wu and Babcock (1998) classified them under human capital, production, policy and natural resource characteristics.

Although there are many categories for grouping determinants of technology adoption, there is no clear distinguishing feature between variables in each category. Categorization is done to suit the current technology being investigated, the location, and the researcher's preference, or even to suit client needs (Bonabana- Wabbi 2002). For instance the level of education of a farmer has been classified as a human capital by some researchers while others classifies it as a household specific factor. This study will review the factors determining adoption of agricultural technology by categorizing them into technological factors, economic factors, institutional factors and household specific factors. This will enable a depth review of how each factor influences adoption.

Technology factors

Characteristic of a technology is a precondition of adopting it. Trialability or a degree to which a potential adopter can try something out on a small scale first before adopting it completely is a major determinant of technology adoption (Doss, 2003). In studying determinants of adopting Imazapyr-Resistant maize (IRM) technology in Western Kenya, Mignouna *et al.* (2011) stated that, the characteristic of the technology play a critical role in adoption decision process. They argued that farmers who perceive the technology being consistent with their needs and compatible to their environment are likely to adopt since they find it as a positive investment. Farmers' perception about the performance of the technologies significantly influences their decision to adopt them. A study by adesina and Zinnah (1993) showed that farmers' perception of characteristic of modern rice variety significantly influenced their decision to adopt it. A similar result was reported by Wandji *et al*. (2012) when studying perception of farmers towards adoption of Aquaculture technology in Cameroon. Their study indicated that perception of farmers towards fish farming facilitated its uptake. It is therefore important that for any new technology to be introduced to farmers, they should be involved in its evaluation to find its suitability to their circumstances (Karugia *et al*., 2004).

Economic Factors

Farm size plays a critical role in adoption process of a new technology. Many authors have analyzed farm size as one of important determinant of technology adoption. Farm size can affect and in turn be affected by the other factors influencing adoption (Lavison 2013). Some technologies are termed as scale-dependant because of the great importance of farm size in their adoption (Bonabana- Wabbi 2002).

Many studies have reported a positive relation between farm size and adoption of agricultural technology (Kasenge, 1998; Gabre-Madhin and Haggblade, 2001 Ahmed, 2004; Uaiene *et al*., 2009; Mignouna et al, 2011). Farmers with large farm size are likely to adopt a new technology as they can afford to devote part of their land to try new technology unlike those with less farm size (Uaiene *et al*., 2009). In addition, lumpy technologies such as mechanized equipment or animal traction require economies of size to ensure profitability (Feder, Just and Zilberman, 1985).

Some studies have shown a negative influence of farm size on adoption of new agricultural technology. Small farm size may provide an incentive to adopt a technology especially in the case of an input-intensive innovation such as a labor-intensive or land-saving technology. Farmers with small land may adopt land-saving technologies such as green house technology, zero grazing among others as an alternative to increased agricultural production (Yaron, Dinar and Voet, 1992; Harper et al, 1990).

Other studies have reported insignificant or neutral relationship with adoption. For instance a study by Grieshop *et al*. (1988), Ridgley and Brush (1992) Waller et al. (1998) Mugisa-Mutetikka et al., (2000), Bonabana- Wabbi (2002) and Samiee et al. (2009) concluded that size of farm did not affect Integrated Pest Management (IPM) adoption implying that IPM dissemination may take place regardless of farmers' scale of operation. Kariyasa and Dewi (2011) also found that extensive of land holdings had no significant effect on the degree of Integrated Crop Management Farmer Field School (ICM-FFS) adoption probability.

The above mentioned studies consider total farm size and not crop acreage on which the new technology is practiced. Since total farm size has an effect on overall adoption, considering the crop acreage with the new technology may be a superior measure to predict the rate and extent of adoption of technology (Lowenberg-DeBoer, 2000). Therefore in regard to farm size, technology adoption may best be explained by measuring the proportion of total land area suitable to the new technology (Bonabana- Wabbi, 2002)

A key determinant of the adoption of a new technology is the net gain to the farmer from adoption, inclusive of all costs of using the new technology (Foster and Rosenzweig, 2010). The cost of adopting agricultural technology has been found to be a constraint to technology adoption. For instance, the elimination of subsidies on prices of seed and fertilizers since the 1990s due to the World Bank-sponsored structural adjustment programs in sub-Saharan Africa has widened this constraint (Muzari *et al*., 2013). Previous studies on determinants of technology adoption have also reported high cost of technology as a hinderance to adoption. The study done by Makokha *et al*. (2001) on determinants of fertilizer and manure use in maize production in

Kiambu county, Kenya reported high cost of labor and other inputs, unavailability of demanded packages and untimely delivery as the main constraints to fertilizer adoption. Cost of hired labor was also reported by Ouma *et al*. (2002) as one among other factors constraining adoption of fertilizer and hybrid seed in Embu county Kenya. Wekesa *et al.* (2003) when analyzing determinants of adoption of improved maize variety in coastal lowlands of Kenya found high cost and unavailability of seeds as one of factors responsible for low rate of adoption.
Off farm income has been shown to have a positive impact on technology adoption. This is because off-farm income acts as an important strategy for overcoming credit constraints faced by the rural households in many developing countries (Reardon *et al*., 2007). Off-farm income is reported to act as a substitute for borrowed capital in rural economies where credit markets are either missing or dysfunctional (Ellis and Freeman, 2004; Diiro, 2013). According to Diiro (2013) off- farm income is expected to provide farmers with liquid capital for purchasing productivity enhancing inputs such as improved seed and fertilizers. For instance, her study when analyzing the impact of off-farm earnings on the intensity of adoption of improved maize varieties and the productivity of maize farming in Uganda, Diiro reported a significantly higher adoption intensity and expenditure on purchased inputs among households with off-farm income compared to their counterparts without off- farm income. However not all technologies has shown positive relationship between off-farm income and their adoption. Some studies on technologies that are labor intensive have shown negative relationship between off-farm income and adoption. According to Goodwin and Mishra (2004) the pursuit of off-farm income by farmers may undermine their adoption of modern technology by reducing the amount of household labor allocated to farming enterprises.

Institutional factors
Belonging to a social group enhances social capital allowing trust, idea and information exchange (Mignouna et al., 2011). Farmers within a social group learn from each other the benefits and usage of a new technology. Uaiene *et al*. (2009) suggests that social network effects are important for individual decisions, and that, in the particular context of agricultural innovations, farmers share information and learn from each other. Studying the effect of community based organization in adoption of corm-paired banana technology in Uganda, Katungi and Akankwasa (2010) found that farmers who participated more in community-based organizations were likely to engage in social learning about the technology hence raising their likelihood to adopt the technologies. Although many researchers have reported a positive influence of social group on technology adoption, social groups may also have a negative impact on technology adoption especially where free-riding behavior exists. Foster and Rosenzweig (1995) when studying adoption of Green Revolution technologies in India found that learning externalities within social networks increased the profitability of adoption, but also farmers appeared to be free-riding on their neighbors' costly experimentation with the new technology. Bandiera and Rasul (2002) as cited by Hogset (2005) suggests that, learning externalities generate opposite effects, such that the more other people engage in experimentation with a new technology, the more beneficial it is to join in, but also the more beneficial it is to free-ride on the experimentation of others. As a result of these contradictory effects, Bandiera and Rasul (2002) propose an inverted U-shaped individual adoption curve, implying that network effects are positive at low rates of adoption, but negative at high rates of adoption.

Acquisition of information about a new technology is another factor that determines adoption of technology. It enables farmers to learn the existence as well as the effective use of technology and this facilitates its adoption. Farmers will only adopt the technology they are aware of or have heard about it. Access to information reduces the uncertainty about a technology's performance hence may change individual's assessment from purely subjective to objective over time (Caswell et al., 2001; Bonabana- Wabbi 2002). However access to information about a technology does not necessarily mean it will be adopted by all farmers. This simply implies that farmers may perceive the technology and subjectively evaluate it differently than scientists (Uaiene *et al*., 2009). Access to information may also result to dis-adoption of the technology. For instance, where experience within the general population about a specific technology is limited, more information induces negative attitudes towards its adoption, probably because more information exposes an even bigger information vacuum hence increasing the risk associated with it (Bonabana- Wabbi 2002). It is therefore important to ensure the information is reliable, consistent and accurate. Farmers need to know the existence of technology, its beneficial, and its usage for them to adopt it.

Access to extension services has also been found to be a key aspect in technology adoption. Farmers are usually informed about the existence as well as the effective use and benefit of new technology through extension agents. Extension agent acts as a link between the innovators (Researchers) of the technology and users of that technology. This helps to reduce transaction cost incurred when passing the information on the new technology

to a large heterogeneous population of farmers (Genius *et al*., 2010). Extension agents usually target specific farmers who are recognized as peers (farmers with whom a particular farmer interacts) exerting a direct or indirect influence on the whole population of farmers in their respective areas (Genius *et al*., 2010).
Many authors have reported a positive relationship between extension services and technology adoption. A good example include; Adoption of Imazapyr-Resistant Maize Technologies (IRM) by Mignouna *et al*. (2011); Factors determining technology adoption among Nepalese Karki and Siegfried (2004); Uaiene *et al*., 2009; Adoption of improved maize and land management in Uganda by Sserunkuuma (2005); adoption of modern agricultural technologies in Ghana Akudugu *et al.* (2012) just to mention a few. This is because exposing farmers to information based upon innovation-diffusion theory is expected to stimulate adoption (Uaiene *et al*., 2009). In fact, the influence of extension agents can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies (Yaron, Dinar and Voet, (1992); Bonabana- Wabbi 2002).

Access to credit has been reported to stimulate technology adoption (Mohamed & Temu, 2008). It is believed that access to credit promotes the adoption of risky technologies through relaxation of the liquidity constraint as well as through the boosting of household's-risk bearing ability (Simtowe & Zeller, 2006). This is because with an option of borrowing, a household can do away with risk reducing but inefficient income diversification strategies and concentrate on more risky but efficient investments (Simtowe & Zeller, 2006). However access to credit has been found to be gender biased in some countries where female-headed households are discriminated against by credit institutions, and as such they are unable to finance yield-raising technologies, leading to low adoption rates (Muzari *et al*., 2013). There is therefore need for policy makers to improve current smallholder credit systems to ensure that a wider spectrum of smallholders are able to have access to credit, more especially female-headed households (Mkandawire, 1993; Simtowe & Zeller, 2006). This may, in certain cases, necessitate designing credit packages that are tailored to meet the needs of specific target groups (Muzari *et al*., 2013). For instance in Kenya, the government has started a program that offer free interest loans to youths and women (UWEZO fund). This will help empower women and enable them to adopt agricultural technologies hence enhancing economic growth.

Household-specific factors
Human capital of the farmer is assumed to have a significant influence on farmers' decision to adopt new technologies. Most adoption studies have attempted to measure human capital through the farmer's Education, age, Gender, and household size (Fernandez-Cornejo & Daberkow, 1994; Fernandez-Cornejo *et al*., 2007; Mignouna et al, 2011; Keelan *et al.*, 2014). Education of the farmer has been assumed to have a positive influence on farmers' decision to adopt new technology. Education level of a farmer increases his ability to obtain; process and use information relevant to adoption of a new technology (*Mignouna et al*., 2011; Lavison 2013; Namara *et al*., 2013). For instance a study by Okunlola *et al.* (2011) on adoption of new technologies by fish farmers and Ajewole (2010) on adoption of organic fertilizers found that the level of education had a positive and significant influence on adoption of the technology. This is because higher education influences respondents' attitudes and thoughts making them more open, rational and able to analyze the benefits of the new technology (Waller *et al*., 1998). This eases the introduction of a new innovation which ultimately affects the adoption process (Adebiyi & Okunlola, 2010). Other studies that have reported a positive relationship between education and adoption as cited by Uematsu and Mishra (2010) include; Goodwin and Schroeder (1994) on forward pricing methods, Huffman and Mercier (1991); Putler and Zilberman (1988) on adoption of microcomputers in agriculture, Mishra and Park (2005); Mishra et al. (2009) on use of internet on use of internet, Rahm and Huffman (1984) on reduced tillage, Roberts et al. (2004) on precision farming and Traore, *et al*. (1998) on on-farm adoption of conservation tillage.

On the other hand, some authors have reported insignificant or negative effect of education on the rate of technology adoption (Grieshop *et al*., 1988; Khanna, 2001; Banerjee, *et al*., 2008; Samiee *et al*., 2009; Ishak and Afrizon, 2011). Studying the effect of education on technology adoption, Uematsu and Mishra (2010) reported a negative influence of formal education towards adopting genetically modified crops. Since the above empirical evidence have shown mixed results on the influence of education and adoption of new technology, more study need to be done in order to come up with a more consistent result.

Age is also assumed to be a determinant of adoption of new technology. Older farmers are assumed to have gained knowledge and experience over time and are better able to evaluate technology information than younger farmers (Mignouna et al, 2011; Kariyasa and Dewi 2011). On contrary age has been found to have a negative relationship with adoption of technology. This relationship is explained by Mauceri et al. (2005) and Adesina &

Zinnah (1993) that as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. On the other hand younger farmers are typically less risk-averse and are more willing to try new technologies. For instance, Alexander and Van Mellor (2005) found that adoption of genetically modified maize increased with age for younger farmers as they gain experience and increase their stock of human capital but declines with age for those farmers closer to retirement.

Gender issues in agricultural technology adoption have been investigated for a long time and most studies have reported mixed evidence regarding the different roles men and women play in technology adoption (Bonabana-Wabbi 2002). In analyzing the impact of gender on technology adoption, Morris and Doss (1999) had found no significant association between gender and probability to adopt improved maize in Ghana. They concluded that technology adoption decisions depend primarily on access to resources, rather than on gender and if adoption of improved maize depends on access to land, labor, or other resources, and if in a particular context men tend to have better access to these resources than women, then in that context the technologies will not benefit men and women equally. On the other hand gender may have a significant influence on some technologies. Gender affects technology adoption since the head of the household is the primary decision maker and men have more access to and control over vital production resources than women due to socio-cultural values and norms (Tesfaye *et al.,* 2001; Mesfin, 2005; Omonona *et al.,* 2006; Mignouna *et al*., 2011). For instance, a study by Obisesan (2014) on adoption of technology found that, gender had a significant and positive influence on adoption of improved cassava production in Nigeria. His result conquered with that of Lavison (2013) which indicated male farmers were more likely to adopt organic fertilizer unlike their female counterparts.

Household size is simply used as a measure of labor availability. It determines adoption process in that, a larger household have the capacity to relax the labor constraints required during introduction of new technology (Mignouna et al, 2011; Bonabana- Wabbi 2002)

Conclusion

This study has reviewed past studies on the factors influencing adoption of agricultural technology. Perception of farmers towards a new technology is a key precondition for adoption to occur. Other factors that have been shown to determine adoption of agricultural technology include human specific factors, economic factors, technological and institutional factors. From the review, the determinant of agricultural technology adoption does not always have the same effect on adoption rather the effect varies depending on the type of technology being introduced. For example, farm size as a determinant of technology adoption has been found to have mixed effect. Large farm size may have positive effect on adoption of a certain technology and it may also reveal a negative impact on adoption of another technology such as zero grazing technology.

Understanding the factors that influence or hinder adoption of agricultural technology is essential in planning and executing technology related programmes for meeting the challenges of food production in developing countries. Therefore to enhance technology adoption by farmers, it's important for policy makers and developers of new technology to understand farmers need as well as their ability to adopt technology in order to come up with technology that will suit them.

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