RESEARCH SERIES No. 102

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TABLE OF CONTENTS

List of Tables

ABSTRACT

The study examines the determinants of improved agricultural technologies adoption in Uganda, using a nationally representative panel data set of 1,600 farming households, collected by the Ugandan Bureau of Statistics in 2005/6 and 2009/10. Two agricultural technologies—improved seeds and fertilizer—out of the seven types identified by the study were further considered and analyzed. Estimates from the probit regression model show that farmers with low education and land holdings are less likely to adopt improved seeds and fertilizer, while peer effects play a big role in influencing farmers to either use improved seeds or fertilizer. Furthermore, cattle keeping farmers in Western Uganda are more likely to abandon fertilizers and possibly resort to organic manure from livestock excreta. Policy, therefore, should be directed at addressing the supply side constraints of agricultural technologies.

Keywords: *Agricultural technologies adoption, Improved seeds and fertilizer, Farming households, Uganda*

ACKNOWLEDGEMENT

The Author acknowledge support from the African Economic Research Consortium (AERC) to undertake this research. I also benefited from comments from George Owour, Innocent Matshe, Isaac Minde, Alberto Zezza and participants at the International Agricultural Economics Association conference in Foz Do Igaucu, Brazil August 2012. I would like to thank the Uganda Bureau of Statistics (UBoS) for making the data available. Any errors are mine.

1. INTRODUCTION

Modern farming methods matter for smallholder agricultural productivity and food security. Adoption of improved agricultural technologies has been associated with: higher earnings and lower poverty (Kassie et al, 2011; Minten et al, 2007), improved nutritional status (Kumar and Quisumbing, 2010), lower staple food prices (de Janvry and Sadoulet, 2002; Karanja et al, 2003), and increased employment opportunities as well as earnings for landless labourers (Binswanger and von Braun, 1991). Indeed, the adoption of improved technologies is heralded as a major factor in the success of the green revolution experienced by Asian countries (Ravallion and Chen, 2004). At the global level, the adoption of improved agricultural technology is now considered critical to the attainment of the Millennium Development Goal (MDG) 1 of reducing extreme poverty and hunger. Although substantial public resources have been devoted to the development and provision of modern crop varieties in Sub-Saharan Africa (SSA) in the past 30 years, overall adoption rates for improved technologies have lagged behind other regions (World Development Report, 2008).[1]

Agriculture remains the mainstay for the majority of Ugandans, although Uganda's agricultural sector has registered very slow growth in the recent past. During 2000-2010, growth in the Ugandan agricultural sector averaged about 2% per annum, compared to 8% and 13% for the manufacturing and services sectors, respectively (Ministry of Finance, Planning and Economic Development-MFPED, 2011). As a consequence, the sector's contribution to total Gross Domestic Product (GDP) declined to less than 20% by 2007/8 from 50% in 1992/93 (MFPED, 2007). Despite the above changes, the agricultural sector continues to employ about 75% of Ugandans (Economic Policy Research Centre, 2009). As such, the performance of the sector will continue to influence the welfare outcomes of majority of Ugandans. The stagnation in agricultural growth happened during the implementation of a number of reforms. For instance, in 2001, the Government of Uganda (GoU) set up the National Agricultural Advisory Services (NAADS) to help refocus attention on agricultural technology dissemination. Indeed, during 2000-2010, on average about 45% of the Ugandan agricultural budget was earmarked for technology development, extension services, and stocking of agricultural inputs (Ministry of Agriculture Animal Industries and Fisheries, 2010).

Overall, in spite of the resources spent on the public extension system in Uganda, there is limited adoption of improved crop varieties, and input use remains generally very low. For instance, only 6% of farmers in Uganda were using improved seeds in 2006, while a much lower proportion used inorganic fertilizers (Uganda Bureau of Statistics, 2007). Even for farmers who initially adopt improved agricultural technologies, dropout rates are high. For instance, Kijima

1 For instance, the 2008 World Development Report shows that in 2000, improved varieties accounted for 24% of the cereal crop area, compared to 59% in Latin America and 77% in South Asia.

et al (2011) shows that about 50% of farmers who adopted the high yielding rice variety (New Rice for Africa—NERICA) abandoned the variety within two years. Such is the situation despite widespread evidence that returns to agricultural technology adoption are high in Uganda. For instance, the World Bank showed that adoption of improved seeds was associated with a 21% increase in crop yields for Ugandan farmers (World Bank, 2006). Consequently, it is important to understand why adoption of agricultural technologies has remained very low in Uganda despite the documented benefits of agricultural technical change.

There are important reasons why we are interested in understanding who adopts agricultural technologies. As highlighted by Oster and Thorton (2009), understanding the process of technology adoption in developing countries can help in: (i) predicting adoption patterns; (ii) supporting adopters to sustain the process given the relatively higher dis-adoption rates; and (iii) knowing the most favourable way of marketing new technologies. In the case of Uganda, the past 10 years have been characterized by introduction of new agricultural interventions, some of which have targeted increasing the adoption of agricultural technologies as means of changing the structure of agricultural production in the country and ultimately farmer incomes. Only few studies have examined the reasons for the limited adoption of agricultural technologies in Uganda. This is because of lack of suitable data that identifies which particular households adopt agricultural technologies, and how the adoption process changes over time. This study, however, is expected to contribute to the list of existing literature on adoption of agriculture in Uganda due to its privileged access to the nationally representative panel survey data on agricultural households collected by the Uganda Bureau of Statistics in 2005/6 and 2009/10. The study, therefore, explores the determinants of agricultural technology adoption in Uganda and how these have changed between 2005/6 and 2009/10, and the extent to which peer effects and/or activities of other farmers in the community influence the rate of adoption.

2. CONCEPTUAL FRAMEWORK

2.1 Process of Agricultural Technology Adoption in Developing Countries

Literature on agriculture highlights two major drivers of successful agricultural technology adoption in developing countries: (i) the availability and affordability of technologies; and (ii) farmer expectations that adoption will remain profitable—both which determine the extent to which farmers are risk averse (Foster and Rosenzweig, 2010; Carletto et al, 2007). A number of factors drive the above expectations, ranging from availability and size of land, family labour, prices and profitability of agricultural enterprises, and peer effects. The conceptual framework presented here highlights the various pathways through which different factors influence household decisions to adopt agricultural technologies.

One of the most highlighted constraints to agricultural technology adoption is the availability of cultivable land (de Janvry et al, 2011; Carletto et al, 2007; Pingali et al, 1987). It is argued that availability of land helps reduce the liquidity constraints faced by households and also reduces risk aversion. On the other hand, ownership of large tracts of land can facilitate experimentation with new agricultural technologies, and also determine the pace of adoption as large land owners are more likely to be the early adopters (de Janvry et al, 2011). On the other hand, the limited availability of land may spur the use of organic fertilizers in a poor resource setting (Pingali et al, 1987). Furthermore, the quality of land may be a major factor in deciding the use of key inputs such as chemical fertilizers, or adopting improved crop varieties due to expected higher returns (Carletto et al, 2007). In the case of a country such as Uganda, with entrenched overlapping and relatively unsecure property land rights (Deininger and Ayalew Ali, 2008), availability of land alone may not spur agricultural technology adoption. Furthermore, even in countries with secure property rights but poorly developed financial markets, land availability may not reduce the credit constraint. In order to address the liquidity and supply constraints faced by poor farmers with regard to technology adoption, a number of African countries have implemented various forms of 'smart subsidies' that target specific farmers (Minde et al, 2008).[2]

Based on extensive studies in Ethiopia, it has been shown that life cycle effects are important drivers of agricultural technology adoption (Kebede et al, 1990; Asfaw and Admassie, 2004). In particular, younger as well as much older household heads are risk averse and are less likely to adopt new technologies. On the other hand, the availability of adult family members within households may facilitate the process of technology because most farming households cannot easily acquire hired labour due to liquidity constraints (Carletto et al, 2007). The same authors also highlight the fact that continued availability of adult household members is a major factor

2 Examples of African countries that provide input subsidies to farmers include Malawi, Zambia, and Kenya.

in determining whether households continue with the technology after making the decision to adopt.

A key determinant of sustained adoption is the profitability of agricultural enterprises. The changing prices for agricultural products are shown to be a major factor in agricultural technology adoption (Kijima et al, 2011). Initially attracted by higher product prices, farmers can abandon the technologies if the expected benefits from adoption are lower than the prevailing costs. There are a number of ways through which profitability of products may be lowered. For cash crops, changes in the international trade regime may negatively affect world prices and consequently depress local prices. The global decline in cotton prices due to cotton subsidies in developed countries best illustrates this fact (Minot and Daniels, 2005). The changing profitability of agricultural enterprises also introduces the time dimension as a driver of adoption—households may adopt technologies for some but not all periods.

Another reason highlighted in the literature, which drives agricultural technology adoption, is peer effects or learning from other farmers. According to Oster and Thorton (2009), in any technology adoption process, peer effects work in three major ways: (1) individuals profit from acting like friends/neighbours; (2) individuals gain knowledge of the benefits of the technology from their friends; and (3) individuals learn about how to use a new approach from peers. With regard to agricultural technology adoption, peer effects can lead to economies of scale by lowering transportation costs but can also lead to increased competition and land prices, which can spur dis-adoption (Carletto et al, 2007). Indeed, some studies, for example Conley and Udry (2010) in Ghana, showed that learning by doing influenced technical change in pineapple cultivation.

Evidence from empirical studies on Africa confirm that Sub-Saharan Africa (SSA) farmers face a host of constraints, ranging from infrastructure, incentives, and liquidity, which impede farmer's adoption and retention of agricultural technology (Kijima et al, 2011; Marenya and Barrett, 2009; Bezu and Holden, 2008; Poulton et al, 2006; and Jayne et al, 2003). Nonetheless, some studies find reasons beyond the above mentioned constraints as forestalling agricultural technology adoption as well. For instance, Marenya and Barret (2009) based on a study in Kenya shows that without addressing complementary factors such as soil quality, merely availing infrastructure alone cannot ensure sustained adoption of agricultural technologies.

2.2 Technology Adoption in Uganda—the NAADS Programme

During the implementation of agricultural reforms in the early 1990s, Uganda abandoned its traditional supply-led extension system that focused on promoting cash crops for exports, that is coffee, cotton, tea, and tobacco. The system was replaced in 2001 with a demand-driven National Agricultural Advisory Services (NAADS). The NAADS programme was part of the wider Plan for Modernization of Agriculture (PMA), whose major objective was to change the orientation of farmers in Uganda—from subsistence to commercial agriculture (Bahiigwa et al, 2005). Unlike the traditional agricultural extension system, the NAADS programme is demand-driven, operating through product-based farmer groups as opposed to the previous producer cooperatives. The programme is financed mainly by donors, and works by way of farmer groups selecting three priority agricultural products for which they request specific technologies and advisory services. The technologies are provided inform of revolving credit, with repayments passed on to other members of the farmer group. Originally, the requested technologies were procured centrally at the district local government level. However, starting in 2008, farmers were given the leeway to procure inputs locally; that is from fellow or neighboring farmers (Ministry of Agriculture Animal Industries and Fisheries , 2010).

Apart from availing information to farmers, another key objective of the NAADS programme is to increase farmer access to productivity enhancing technologies. In order to meet this objective, the programme has over time devoted increasing resources to the provision of inputs, and as such the programme accounts for the bulk of the public agricultural sector budget. For instance, the share of non-wage recurrent spending on agriculture increased from 49% in 2005/06 to 80% by 2008/09 due to input provision under the NAADS programme (World Bank, 2010). On the other hand, the share of the NAADS programme in the agricultural budget increased from 10% in 2003/04 to 50% by 2010/11. Projections under the medium term expenditure framework suggest that NAADS will account for about 60% of the agricultural budget by 2016/17 (MFPED, 2011).

Overall, Uganda's NAADS programme addresses a number of binding constraints faced by farmers in most developing countries as highlighted in section 2.1 above. First, the programme provides framers with information on inputs, production, and the market. Second, the programme addresses the liquidity constraints faced by most farmers in SSA. Third, by working through farmer groups and prioritizing agricultural products, the programme attempts to attain economies of scale, which can lower the cost of agricultural production. Recent evaluation of the NAADS programme reveals that the NAADS programme has had minimal impact on agricultural technology adoption in Uganda. Specifically, the study by Benin et al (2011) based on panel survey of farmers in 2004 and 2007 found that farmers participating in NAADS programmes were significantly more likely to adopt the recommended planting and spacing practices only. There were no significant differences between NAADS farmers and the controls on adoption of improved seeds and livestock breeds, inorganic fertilizers, and pesticides. The authors attribute the above results to the fact that adoption of agricultural technologies after extension advice requires resources, and in case of binding credit constraints, the envisaged change may not materialize. As such, the evidence is still inconclusive regarding the efficacy of extension services on agricultural extension.

The literature on agricultural technology adoption in Uganda has expanded in the recent past (see for example Benin et al, 2011; Kassie et al, 2011; Kijima et al, 2011; Sserunkuma, 2005; Deininger and Okidi, 2001). However, the Ugandan literature is based on small samples and, in most cases, focuses on specific agricultural products. For instance, Kijima et al (2011) examine the reasons for the high dis-adoption rates for the NERICA rice introduced in Uganda in 2002. Using a panel survey of 347 households, the authors point to the relatively low profitability of rice in comparison to other agricultural products, distances to rice milling centres, and consequently higher costs of marketing as the reasons for the high dis-adoption rates. On the other hand, Sserunkuuma (2005), based on a survey of 450 households, examines the reasons for low adoption of maize varieties in Uganda and find that participation in agricultural extension programmes is a key determinant of adoption of maize varieties.

Uganda provides a good case for investigating issues concerning agricultural technology adoption for a number of other reasons. First, since 2001, Uganda has implemented a large scale agricultural extension programme (NAADS) whose key objective was to increase farmer's knowledge and use of improved technologies. With over 30% of the agricultural budget devoted to extension delivery, it is important to know to what extent this has translated into technology adoption by smallholder farmers.[3] Second, as earlier noted, recent research shows that dis-adoption rates are quite high (Kijima et al, 2011). As such, it is important to know the reasons why agricultural technology dis-adoption may occur using a nationally representative survey. Finally, with the exception of the study by Deininger and Okidi (2001), the other studies are based on small samples and selected products.[4] The study by Kassie et al (2011) focused on the impact of adoption of groundnut varieties.

3 Indeed, there is considerable public interest in performance of the extension system as highlighted by the attacks on the management of the NAADS programme by both the government and the opposition politicians during the presidential and parliamentary election campaigns in early 2011.

4 Although the study by Deininger and Okidi (2001) is based on nationally representative panel data, it nonetheless captures farming information for the period 1992-1999. Since that time, there have been significant changes in the methods and types of products cultivated by Ugandan farmers.

3. METHODOLOGY

3.1 Data

We utilize the panel survey of 1,600 farming households covered during the 2005/06 and 2009/10 survey conducted by the Uganda Bureau of Statistics (UBS). The panel survey is part of the regular Uganda National Household Surveys (UNHS) undertaken in 2005/06 and 2009/10. The UNHS surveys were modeled along the lines of the multi-topic World Bank's Living Standard Measurement Surveys (LSMS). The 2005/06 and 2009/10 surveys were based on the two-stage stratified random sampling procedure. In the first stage, the enumeration area (EA) stratified according to spatial location were the principal sampling unit, and the selections of EAs, was based on the 2002 census as the frame. In the second stage, 10 households were randomly selected from each of the EAs. The 2005/06 UNHS collected information from 7,424 households (from 760 EAs) of which 72% were engaged in agriculture (UBS, 2007). As part of wider efforts to monitor government programmes, UBS reinstated the annual Uganda National Panel Survey (UNPS) in 2009.[5] The first wave was undertaken during September 2009-August 2010 and covered 320 EAs. Information was collected from 1,600 households, all part of the agricultural households covered during 2005/06.

The agricultural information from both surveys was collected through two household visits—six months apart—to account for the two agricultural seasons experienced in most parts of Uganda. In 2005/06, the agricultural module captured information including: household land holdings; type and quality of soils used for cultivation; investments on land; types of crops produced, and the use of improved seeds; the use of organic and chemical fertilizers; agricultural labour inputs; and access to extension services.

With regard to agricultural technology adoption, the 2005/06 collected information on access of and demand for agriculture technology.[6] Specific information was collected on use of fertilizers[7] and improved varieties during the 2004/05 cropping season. In order to capture the quality of the land as well as the topography, we include qualitative indicators of soil quality as well as categorical variables for land on: hilly areas, slopes, or valleys. To capture peer effects, we generate a community level variable for extent of fertilizer or improved seed use.

The survey also contained a quiz to test farmer's knowledge of agricultural technologies as well as improved varieties. Seven questions were asked concerning: (1) crops that improve soil fertility; (2) cassava planting methods that provide the best results; (3) cropping methods that

5 The major objective of the UNPS is to provide annual nationally representative estimates of outcomes of key government programmes.

6 Seven types of agricultural technologies were considered: (1) soil fertility management; (2) crop protection; (3) farm management; (4) improved produce quality/varieties; (5) off-farm storage; (6) improved individual and group marketing; and (7) animal disease control.

7 These include organic fertilizers, inorganic fertilizers, and pesticides.

increase susceptibility to pests and crop diseases; (4) crops that follow beans in a rotation; (5) the number of banana plants in each stand; (6) the most common pest that affects bananas; and (7) the recommended quantity of DAP fertilizer when planting maize. We generate a variable, which is total score of the correct answers to agricultural technology quiz. For knowledge about improved varieties, the test enquired about awareness of improved varieties for cassava, maize, beans, bananas, finger millet, Sim sim and Irish potatoes. Again, we generate a score for answers regarding knowledge of varieties.

Finally, the survey enquired from farmers whether they had used any of the stated varieties in the past 12 months or used in the past. We use the latter variables as dependent variables to establish differences in drivers of current and past use of improved varieties. The descriptive statistics of the variables used are provided in Table 1.

Table 1: Descriptive statistics of variables used

	All	By Agricultural Technology Adoption			
	Panel	Used Improved		Fertilizer	
	Households	2005/06	2009/10	2005/06	2009/10
Land owned (acres)	3.9	4.5	4.5	4.4	5.1
Soil quality is good =1	0.59	0.65	0.66	0.65	0.62
Household land is hilly=1	0.15	0.13	0.11	0.19	0.18
Household land is on a slope=1	0.52	0.53	0.52	0.61	0.62
Household land is in a valley=1	0.06	0.06	0.06	0.08	0.06
Age of household head (years)	44	44	41	45	41
Education of the household head					
No education	0.20	0.12	0.13	0.14	0.06
Some primary	0.43	0.38	0.42	0.39	0.48
Completed primary school	0.14	0.14	0.14	0.16	0.12
Some secondary school	0.16	0.21	0.20	0.19	0.21
Completed secondary school and above	0.08	0.15	0.11	0.12	0.13
Number of adults in 2005	2.4	2.8	2.6	2.7	2.6
Number of adults in 2009	2.4	2.9	2.6	2.7	2.7
Consumption per adult equivalent in 2005/06	52,701	61,652	55,525	63,425	58,614
Consumption per adult equivalent in 2009/10	73,957	68,779	63,256	74,889	70,396
Community use of improved seeds in 2005/06	0.19	0.29	0.22	0.21	0.25
Community use of fertilizer in 2005/06	0.25	0.27	0.22	0.47	0.34
Community use of improved seeds in 2009/10	0.21	0.26	0.39	0.20	0.32
Community use of organic fertilizer in 2009/10	0.13	0.14	0.11	0.23	0.16
Community use of inorganic fertilizer in 2009/10	0.03	0.04	0.06	0.04	0.09
Community use of pesticides in 2009/10	0.11	0.16	0.17	0.17	0.29
Availability of input markets in 2005/06	0.18	0.19	0.17	0.16	0.13

	All	By Agricultural Technology Adoption			
	Panel	Used Improved		Fertilizer	
	Households	2005/06	2009/10	2005/06	2009/10
Availability of organic fertilizer market in 2009/10	0.01	0.01	0.02	0.02	0.03
Availability of inorganic fertilizer market in 2009/10	0.02	0.06	0.07	0.05	0.17
Availability of chemical fertilizer market in 2009/10	0.08	0.17	0.19	0.18	0.63
Availability of improved seed market in 2009/10	0.11	0.18	0.52	0.14	0.28

3.2 Estimation Procedure

We estimate the following relationship between agricultural technology adoption, household and farm characteristics, as well as peer effects and farmer knowledge of crop practices.

Eq (1) $$Adoption_i = \gamma + \delta_1(Farmer\_Knowledge) + \delta_2(Peer\_Effects) + \Pi X_i + \mu_i$$

where X_i is a vector of controls (for example age of the household head, gender, school attainment, and poverty status), and farmer knowledge represents variables relating to exposure to agricultural technologies prior to the survey. Peer effects mainly capture the sources of agricultural technology information. We define agricultural technology adoption as a binary variable and we use two variants of indicators of agricultural technology adoption, including: (1) use of fertilizers; and (2) use of improved crop varieties. Since we have information from the same household in 2005/06 and 2009/10, we estimate variants of equation (1) above such as agricultural technology adoption in 2005/06 and adoption in 2009/10.

4. RESULTS

This section reports the probit regression results from estimating equation (1). In all estimations, we utilize clustered standard errors. First, we consider determinants of use of improved seeds and fertilizers in both 2005/06 and 2009/10. Table 2 shows the determinants of agricultural technology adoption. The first two columns show the results for adoption in 2005/06, and it is indicated that farm size is an insignificant correlate of agricultural technology adoption. Also, agro-ecological controls are generally insignificant, with the exception for the 2009/10 survey round where households with hilly land parcels are less likely to use improved seeds, but more likely to use fertilizers. Table 2 also shows that life cycle effects are only significant in 2009/10 and not 2005/06. In particular, older household heads are significantly less likely to use either improved seeds or fertilizers. Apart from the issue of risk aversion highlighted earlier, this particular result may also be partly explained by the high susceptibility to poor health by older household heads. This can lead to abandoning of new or complex agricultural practices (Rahm and Huffman, 1984).

Furthermore, it is indicated that higher education attainment is associated with an increasing likelihood of use of fertilizers, especially in 2009/10. Other results in Table 2 show that the number of adult household members matters for agricultural technology adoption. This may be partly explained by the fact that there are currently only a few agricultural products in Uganda with improved varieties, and these specific products are labour intensive. At the regional level, farmers in Western Uganda were significantly less likely to use improved seeds in 2005/06 but more likely than farmers in all other regions to use fertilizers. By 2009/10, the regional differences were eliminated. Table 2 also shows that peer effects are important correlates of agricultural technology adoption. Finally, Table 2 highlights the importance of supply side constraints as determinants for availability of key agricultural technologies. In particular, communities with good access to input markets are far significantly more likely to use either improved seeds or fertilizers in both survey rounds (2005/06 and 2009/10).

Table 2: Determinants of agricultural technology adoption in 2005/06 and 2009/10

	2005/06		2009/10	
Dependent Variable	**Improved Seeds**	**Fertilizer**	**Improved Seeds**	**Fertilizer**
	(1)	**(2)**	**(3)**	**(4)**
Log of land owned (acres)	0.359	0.497	0.170	-0.568
	[0.39]	[0.40]	[0.38]	[0.46]
Log of land owned squared	-0.123	-0.169	-0.089	0.323
	[0.19]	[0.19]	[0.18]	[0.22]
Soil quality is poor	-0.007	-0.003	-0.119	0.067
	[0.09]	[0.10]	[0.12]	[0.14]
Household land is hilly=1	0.104	-0.108	-0.208*	0.272**
	[0.11]	[0.11]	[0.12]	[0.13]

	2005/06		2009/10	
Dependent Variable	**Improved Seeds**	**Fertilizer**	**Improved Seeds**	**Fertilizer**
	(1)	**(2)**	**(3)**	**(4)**
Household land is on a slope=1	-0.076	0.056	0.076	0.144
	[0.09]	[0.08]	[0.09]	[0.10]
Household land is in a valley=1	-0.065	-0.068	0.084	-0.049
	[0.18]	[0.15]	[0.15]	[0.18]
Log of age of the household head	-0.053	-0.056	0.551***	-0.329**
	[0.12]	[0.12]	[0.13]	[0.15]
Some primary	0.017	0.055	0.054	0.652***
	[0.11]	[0.10]	[0.12]	[0.18]
Completed primary school	0.161	0.189	0.017	0.449**
	[0.14]	[0.15]	[0.14]	[0.22]
Some secondary school	0.196	0.166	0.215	0.648***
	[0.15]	[0.14]	[0.14]	[0.20]
Completed secondary school and above	0.408**	0.170	0.253	0.739***
	[0.17]	[0.18]	[0.17]	[0.23]
Number of adults in the household	0.106***	0.088***	0.092***	0.040
	[0.03]	[0.03]	[0.03]	[0.03]
Log of consumption per adult equivalent	0.031	0.056	0.066	0.172***
	[0.07]	[0.08]	[0.06]	[0.06]
Household keeps livestock	0.019	0.128	0.252***	0.256**
	[0.08]	[0.10]	[0.08]	[0.10]
Score of knowledge of improved varieties	0.200***	0.055***	0.026	
	[0.02]	[0.02]	[0.02]	

Numbers in [..] are standard errors

Table 2: Continued

	2005/06		2009/10	
Dependent Variable	**Improved Seeds**	**Fertilizer**	**Improved Seeds**	**Fertilizer**
	(1)	**(2)**	**(3)**	**(4)**
Community use of improved seeds	1.413***		3.614***	
	[0.28]		[0.17]	
Community use of fertilizer		3.554***		
		[0.12]		
Community use of inorganic fertilizer				1.557**
				[0.61]
Community use of pesticides				4.120***
				[0.32]
Availability of input markets	0.010	-0.086		
	[0.12]	[0.05]		
Availability of organic fertilizer market			1.041***	0.868***
			[0.33]	[0.34]
Availability of chemical fertilizer market			0.730***	
			[0.25]	
Availability of pesticides market			0.313**	
			[0.12]	
Availability of market for improved seeds				0.505***

	2005/06		2009/10	
Dependent Variable	**Improved**	**Fertilizer**	**Improved**	**Fertilizer**
	Seeds		**Seeds**	
	(1)	**(2)**	**(3)**	**(4)**
				[0.12]
Eastern	0.160	-0.029	0.066	0.116
	[0.12]	[0.06]	[0.09]	[0.09]
Northern	-0.139	-0.112	0.140	-0.009
	[0.13]	[0.08]	[0.11]	[0.11]
Western	-0.281**	0.114*	-0.000	-0.178
	[0.14]	[0.06]	[0.10]	[0.11]
Constant	-2.116***	-2.834***	-0.927	-3.378***
	[0.79]	[0.94]	[0.81]	[0.85]
Number of observations	1,639	1,606	1,639	1,606

Numbers in [..] are standard errors

To what extent is observed adoption behaviour influenced by prior agricultural knowledge? The variable for farmer's knowledge of improved varieties (as captured by the score on tests of improved varieties) shows that this is a key determinant of adoption of improved seeds and fertilizer use in 2005/06 and, by 2009/10, the effect was insignificant. This particular result may be partly explained by the proliferation of the NAADS programme in Uganda, given that the programme has been a major vehicle for disseminating agricultural information. For the first years of the NAADS programme (2001-2006), it only operated in about one third of sub-counties in Uganda. It was not until 2007/08 that the programme was rolled out across the country. Other indicators that are insignificant relate to household wealth status and ownership of livestock. It is only for fertilizer use in 2009/10 that the log of household consumption per adult equivalent is significant. On the other hand, ownership of livestock is positive and significantly associated with agricultural technology adoption in 2009/10.

Table 3: Determinants of agricultural technology adoption by farm sizes and education attainment

	2005/06		2009/10	
Dependent Variable	Improved	Fertilizer	Improved	Fertilizer
	Seeds		Seeds	
	(1)	(2)	(3)	(4)
Second quartile of land acres	0.163	0.314**	-0.060	0.177
	[0.12]	[0.13]	[0.15]	[0.17]
Third quartile of land acres	0.438***	0.263**	-0.081	0.125
	[0.14]	[0.13]	[0.14]	[0.18]
Fourth quartile of land	0.343**	0.389***	0.028	0.224
	[0.15]	[0.15]	[0.16]	[0.18]
[First quartile of land]X[Secondary education]	0.455*	0.144	0.329	0.909***
	[0.25]	[0.26]	[0.24]	[0.31]
[Second quartile of land]X[Secondary Education]	0.389*	0.046	0.735***	0.586**

	2005/06		2009/10	
Dependent Variable	Improved Seeds	Fertilizer	Improved Seeds	Fertilizer
	(1)	(2)	(3)	(4)
	[0.22]	[0.24]	[0.23]	[0.28]
[Third quartile of land]X[Secondary education]	0.551**	0.491**	0.250	0.617**
	[0.23]	[0.23]	[0.21]	[0.31]
[Fourth quartile of land]X[Secondary Education]	0.272	0.023	-0.061	0.794***
	[0.21]	[0.22]	[0.22]	[0.27]
Log of age of the household head	-0.066	-0.053	-0.526***	-0.326**
	[0.12]	[0.12]	[0.13]	[0.15]
Some primary	-0.009	0.045	0.058	0.633***
	[0.11]	[0.10]	[0.12]	[0.18]
Completed primary school	0.123	0.177	0.027	0.433*
	[0.15]	[0.15]	[0.14]	[0.22]
Some secondary school	-0.238*	-0.019	-0.098	-0.092
	[0.14]	[0.16]	[0.15]	[0.18]
Demographic variables	YES	YES	YES	YES
Community use of seeds	YES	YES	YES	YES
Community use of fertilizers	YES	YES	YES	YES
Regional variables	YES	YES	YES	YES

*-significant at 0.10, **-significant at 0.05 and ***-significant at 0.01

It is possible that particular farmer characteristics may influence agricultural technology behaviour. For instance, farmers with small farm sizes may be credit constrained, and such resource poor farmers may not be able to purchase key inputs. At the same time, poorly educated farmers may also have small land parcel, and are as such more likely to seek off-farm employment and are, as a consequence, less likely to engage in intensive agricultural practices. In order to investigate such issues, we interact variables for landholding with education attainment. In particular, we generate quartiles of farm sizes and interact these categorical variables with attainment of secondary education. The results for both 2005/06 and 2009/10 are presented in Table 3. The interaction terms are very significant for the use of improved seeds in 2005/06 and for the second quartile in 2009/10. This suggests that poorly educated farmers are more likely to work on other people's farms without necessarily adopting agricultural technology.

Dis-adoption of agricultural technology occurs regularly in developing countries. The reasons for dis-adoption can range from life cycle effects to changes in the profitability of agricultural products. In Table 4, we investigate the determinants of dis-adoption by 2009/10 of either improved varieties or fertilizer use for farmers who were initially using these technologies in 2005/06. Indications are that the peer effects as captured by the extent of use of improved varieties in the communities slows down the process of improved seed dis-adoption.

Furthermore, farmers from Western Uganda are less likely to abandon the use of improved seeds. On the other hand, the increasing presences of adults in the household, and farmers with a higher knowledge of improved seeds in 2005/06 as well as farmers from Eastern Uganda will more likely dis-adopt improved seeds. With regard to fertilizer dis-adoption, Table 4 shows that older household heads are more likely to abandon fertilizers. Previous studies such as Carletto et al (2007) highlight the fact that pressure to withdraw from agricultural technologies set in after 20 years of use.

Table 4 also indicates that households that keep cattle are more likely to abandon fertilizer use after some time. This may be explained by the increased availability of organic fertilizer/manures with the presence of livestock on household farmers. Livestock excrement may over time become a cheaper although less effective alternative to inorganic fertilizers. Furthermore, animal manure is less amenable to supply side constraints than chemical fertilizers. At a regional level, farmers from Western Uganda were more likely to abandon fertilizers compared to farmers from central Uganda. Given that Western Uganda accounts for the largest share of livestock in Uganda, the above results are also linked to increased availability of organic fertilizer from livestock.

5. CONCLUSIONS AND IMPLICATIONS

In conclusion, this study has examined the determinants of agricultural technology adoption in Uganda using a recently available panel data set collected in 2005/06 and 2009/10. We focus on two types of agricultural technologies—improved seeds and fertilizer use. We find that farmers with low education and land holdings are less likely to adopt agricultural technologies. In addition, we find that peer effects play a big role in influencing farmers to either use improved seeds or fertilizers. Furthermore, dis-adpotion of agricultural technologies occurs regularly, with cattle keeping farmers in Western Uganda more likely to abandon fertilizers and possibly resort to organic manure from livestock excreta.

Our results also have pertinent policy implications, especially regarding addressing supply side constraints. In particular, the relatively limited adoption and sustained use of agricultural technologies is partly because technologies are not readily available in agricultural markets. Sourcing such inputs from distant markets can reduce the profitability and eventual duration of adoption. As such, there is need for the government to lessen the supply side constraints. The introduction of a fertilizer subsidy may help develop the local fertilizer market and lessen the supply side constraints to agricultural technology adoption.

Table 4: Determinants of dis-adoption by 2009/10

	Improved seeds	Fertilizers
Log of land owned (acres)	-0.015	0.015
	[0.40]	[0.38]
Log of land owned squared	0.075	0.009
	[0.19]	[0.18]
Soil quality is poor	-0.023	0.170*
	[0.10]	[0.09]
Household land is hilly=1	0.249**	0.027
	[0.12]	[0.11]
Household land is on a slope=1	-0.097	0.065
	[0.09]	[0.09]
Household land is in a valley=1	-0.138	0.153
	[0.17]	[0.14]
Log of age of the household head	0.108	0.265**
	[0.12]	[0.11]
Some primary	0.051	0.066
	[0.11]	[0.10]
Completed primary school	0.125	0.251
	[0.15]	[0.16]
Some secondary school	0.149	0.095
	[0.15]	[0.14]
Completed secondary school and above	0.236	0.299*
	[0.18]	[0.17]

	Improved seeds	Fertilizers
Number of adults in the household	0.056*	0.018
	[0.03]	[0.03]
Log of household consumption per adult equivalent	-0.062	0.010
	[0.07]	[0.07]
Household keeps livestock	-0.079	0.186**
	[0.09]	[0.08]
Score of knowledge of improved varieties	0.161***	
	[0.02]	

Figure in [..] are standard error

Table 4: Continued

	Improved seeds	Fertilizers
Community use of improved seeds	-1.347***	
	[0.32]	
Community use of in-organic fertilizer		1.111
		[0.72]
Community use of pesticides		-0.447
		[0.34]
Eastern	0.313**	0.028
	[0.13]	[0.13]
Northern	-0.149	-0.345**
	[0.16]	[0.15]
Western	-0.426***	0.380***
	[0.16]	[0.14]
Constant	-1.074	-2.319***
	[0.84]	[0.87]
Observations	1,572	1,546

Numbers in [..] are standard error

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