Effects of Agricultural Extension Services on Farm Productivity in Uganda

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and

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Research Paper 379

Bringing Rigour and Evidence to Economic Policy Making in Africa

AFRICAN ECONOMIC RESEARCH CONSORTIUM
CONSORTIUM POUR LA RECHERCHE ÉCONOMIQUE EN AFRIQUE

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AERC Research Paper 379
African Economic Research Consortium, Nairobi
June 2020

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

ISBN 978-9966-61-072-0

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Acknowledgements

Our appreciation goes to the African Economic Research Consortium (AERC) for the support ; all resource persons for their invaluable and technical inputs and other researchers in the thematic group for making this initiative a success. We assume full responsibility for views reflected in the formulation of this paper.

Abstract

Improving agricultural productivity in Uganda remains a major policy objective given the key role of agriculture in the economy. In this study we evaluate the impact of access to extension services on farm productivity. We use comprehensive baseline survey data collected for monitoring and evaluation of the Agricultural Technology and Agribusiness Advisory Services (ATAAS) project. Applying the ivtreatreg Stata command, and probit 2-stage least squares (2SLS) model that addresses the selection and endogenous bias, we found that access to extension services does not significantly improve the crop productivity of farmers. The finding is consistent with similar studies that control for selection and endogenous bias when estimating treatment effects. We argue that the insignificance of extension contact on productivity when selection and endogenous effects are addressed may reflect the inefficiency of the current extension services in improving farmers' productivity. In conclusion, the study shows that increasing extension impact on farm productivity will require efforts to improve the quality of extension services that directly translate into productivity effects.

1.0 Introduction

It is widely recognized that increasing agricultural growth in many African economies is an important component of a strategy to reduce poverty and hunger (Dercon et al., 2008). This is because the majority of the population in these economies live in rural areas and their survival directly or indirectly depends on agriculture. In Uganda, the agricultural sector is the major employer and a source of livelihood for over three quarters of the population. The sector employs at least 70 per cent of all Ugandans in the labour force. However, productivity growth in agriculture in Uganda, currently ranging between 1.3% and 2.6%, is below the 6% per annum target of the Maputo 2003 Comprehensive Africa Agriculture Development Programme (CAADP). This growth in agriculture is not impressive and has failed to keep pace with that achieved in the rest of the world despite the enormous investment in agricultural research and extension (Nahdy, 2004). If the agricultural sector's growth remains insufficient, poverty and inequality will not be adequately addressed in these economies. Therefore, boosting agricultural productivity to improve the living standards of agricultural households is on the policy agenda for many developing countries in Africa.

There is a strong belief in Uganda that if all 40 million hectares of arable land is worked to its full potential, every Ugandan will be able get out of poverty. For example, in the CAADP, Uganda committed, firstly, to the principle of agriculture-led growth as a main strategy; secondly, to the pursuit of a 6-per-cent average annual growth rate for the agricultural sector; and thirdly, to increasing the share of the national budget allocated to the agricultural sector (MAAIF, 2010). The Plan for Modernization of Agriculture (PMA) also aimed to increase the contribution of agriculture in the economy and thus reduce mass poverty. One of the key components of the PMA was to improve delivery of agricultural extension through the National Agricultural Advisory Services (NAADS) programme (Sebaggala and Okello, 2010; Benin et al., 2007). It is not surprising that this component has absorbed the largest share of total agriculture spending in the recent past. For instance, the overall allocation to agricultural extension increased from 25% of total sector spending in 2005/06 to nearly 43% in 2009/10 (Lukwago, 2010).

The NAADS programme was introduced as a response to the failure of the traditional extension approach to bring about greater productivity and the expansion of agriculture, despite costly government interventions (World Bank, 2001; MAAIF, 2000). NAADS has been operational since 2001 and has changed extension services from a government-run service into a partly-privatized system of "demand-driven" services positioned to empower farmers to demand and control agricultural advisory services. It is demand-driven in the sense that farmers are meant to make their own decisions about whether to participate, and about the kind of activities to engage in during the learning process. It was expected that NAADS would overcome the institutional constraints that were perceived to undermine farmers' access to quality knowledge and productivity enhancing technologies. The programme has attracted massive investment from the government and donors in the last 10 years.

There is some evidence that the NAADS programme has had a positive impact on the availability and quality of advisory services provided to farmers, promoting the adoption of new crop and livestock enterprises, and improving the adoption and use of modern agricultural production technologies and practices (Benin et al., 2007). However, the growth and performance of the agriculture sector has been dismal and declining from 2.4% in the financial year 2009/10, to 0.3% in the financial year 2011/12 (MFPED, 2009; 2012). For example, farmers' yields for the majority of crops have been stagnant or decreasing and any output gains are attributed primarily to the expansion of cultivated land (Betz, 2009; Salami et al., 2010). To harness the structural transformation of agriculture and to boost productivity and commercialization, the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) has been implementing the Development Strategy and Investment Plan (DSIP) for the agriculture sector, covering the period 2010/11 to 2014/15. One of the sub-programmes of DSIP is the ongoing Agricultural Technology and Agribusiness Advisory Services (ATAAS) project, which aims at technology generation, provision of agri-business advisory services, and creating the necessary interface between agricultural research via the National Agricultural Research Organization (NARO), and agricultural advisory (extension) services via National Agricultural Advisory Services (NAADS). Given the fact that interventions such as PMA and NAADS had not been very effective in impacting on productivity (Benin et al. 2007), it is imperative to evaluate the effects of existing extension services on the productivity of farmers. This study investigates the effects of agricultural extension services on farm yields in Uganda.

Available empirical evidence from previous studies on the effect of extension services on agricultural productivity in Uganda provides mixed results (see, e.g., Hasan et al., 2013; Nkonya et al., 2009; Benin et al., 2010 and 2007; Betz, 2009 and 2011; Obwona, 2000; Muwonge, 2007). There are few rigorous impact evaluations of extension services in developing countries (Anderson and Feder, 2007; Evenson, 2001), and the available evidence is contradictory (Feder and Slade 1986; Feder et al., 1987; Hussain et al., 1994). While an extension programme led to a 15% increase in economic returns for wheat in India (Feder and Slade 1986; Feder et al., 1987), there were only small impacts on wheat output in Pakistan (Hussein et al., 1994), and no impact on fruit yields in Uruguay (Maffioli et al., 2015). Generally, there is no consensus on the size of returns on extension investments.

The equivocal evidence on return on extension has raised skepticism among policy makers and development practitioners about the effectiveness of investments in agricultural extension. Evidence from empirical reviews and studies highlight concerns over data quality and methodological issues regarding causality between extension inputs (see World Bank, 2011; Alston et al., 2000; Evenson, 2001; Anderson, 2007; Odhiambo and Nyangito, 2003; Betz, 2009; Anderson and Feder, 2004). A typical case fuelling this concern was the Bindlish and Evenson (1993) study in Kenya. The study found that access to extension services, as measured by the log of the extension-staff-to-farms ratio, had a positive and statistically significant impact on the value of farm production. In a study by Gautam and Anderson (1999), using the same data after incorporating district fixed effects, the positive impact disappeared. In Uganda's case, Muwonge (2007) found that the significant positive impact of NAADS on yields disappears after controlling for endogeneity. This implies that the available empirical evidence on the effects of extension services on productivity is not conclusive, largely because of methodological challenges related to endogeneity and heterogeneity due to programme participation and the presence of unobservable characteristics.

The majority of existing studies on the impact of agricultural extension on productivity and other outcomes assume that extension services come from only one source – extension workers. Therefore, dummy variables indicating whether a farmer had been visited by an extension worker or not, or the number of visits by an extension worker, have been used as variables to capture extension contact. The use of an extension contact variable has an implied assumption that agricultural extension information is only obtained from extension workers. This implies that the available evidence on the impact of extension does not take into account information exchange between farmers and other sources of agriculture information, such as radio, farmer-to- farmer, television, telephone, internet, newspapers, magazines/ bulletins, and agriculture shows/exhibitions, among others. Thus the estimated coefficient on the extension variable from a number studies is biased downward. It is true that the majority of farmers receive benefits of extension without interacting directly with extension workers. This study closes that gap by defining agricultural extension access to include agricultural advisory/extension services arising from various sources. These include: fellow farmers, NAADS service providers, other local government extension workers, NARO researchers, other public agencies (such as Uganda Coffee Development Authority (UCDA), Daily Development Authority (DDA), Cotton Development Organisation (CDO), non-governmental organizations (NGOs)/ Community Based Organization (CBO), farmer organizations/ Savings and Credit Co-operative (SACCO), private sector service providers, traders/input suppliers, newspapers and magazines, radio, internet, and call centres (NAADS, 2015).

The quantitative evidence supporting the ability of extension services to increase productivity is scarce. The lack of evidence is at least partly due to the fact that documenting quantitative changes and attributing them to extension is inherently difficult. This study addresses the methodological challenges that have undermined previous studies in linking agricultural extension and farm productivity, particularly endogeneity and unobserved heterogeneity. Controlling for endogeneity, for example, provides a more accurate description of the causal impact of agricultural extension on productivity. From a policy perspective, such an analysis is important for at least two reasons. First, by accurately quantifying the productivity effects of agricultural extension contact, policy makers are informed about the benefits of policy strategies aimed at assisting farmers to become more productive through extension services. Second, the analysis provides information about the relative importance of the various farm inputs that determine farm productivity.

2.0 Literature Review

2.1 Agricultural extension services delivery in Uganda

In order to raise farmers' income and production in developing countries, governments have been aggressively promoting and reforming agricultural extension services in their countries. Uganda has been experiencing major changes in its agricultural extension system, which can be summarized as: regulatory from 1920 to 1956, advisory from 1956 to 1971, dormancy from 1972 to 1981, and then various educational programmes from 1982 to 1997. Following the introduction of a decentralized system of governance in 1997, the provision of agricultural extension and other agricultural support services became the responsibility of local governments (Benin et al., 2011). Government decentralized extension services with the expectation that the services will be closer to the people, and more relevant to their specific needs. Consequently, the provision of agricultural extension and other agricultural support services became the responsibility of local governments in 1997, as per the Local Government Act 1997 (Benin et al., 2007). According to the provisions of the Act, local governments are responsible for liaising with central government and district level policy makers for planning, coordinating, monitoring and implementing development programmes, including those for agricultural extension. The decentralization process faced several challenges resulting from a number of market failures. For instance, extension provision operations were constrained by a lack of funds to facilitate the work of extension agents at the local government level (Sserunkuuma and Pender, 2001).

Therefore, the rationale for the recent reforms and reorganization of extension service provision arrangements was a failure of traditional extension approaches to bring about greater productivity and expansion of agriculture, despite costly government interventions (MAAIF 2000; Mangheni and Mubangizi, 2007). The shift towards greater private-sector participation in the provision of extension services is also attributed to the perceived inefficiency, irrelevance and non-responsiveness of public extension and budget constraints (Mangheni and Mubangizi, 2007). Thus, a publicly financed privately delivered extension system was adopted in 2001 to rectify past weaknesses related to rising concerns of inefficiency of government-led extension, such as the inability of central government to handle the complexity of context-specificity required by extension services and the inability of government to finance the requisite range of services, as well as to incorporate "best" practices in order to make extension delivery more efficient and effective (PMA, 2000).

The NAADS programme was initiated in 2001 in six trailblazing districts (i.e., Arua, Kabale, Kibaale, Mukono, Soroti and Tororo), within which the NAADS programme began in 24 sub-counties. In 2002/03, NAADS was rolled out to ten new districts (Bushenyi, Busia, Iganga, Kabarole, Kapchorwa, Kitgum, Lira, Luwero, Mbarara and Wakiso), covering 46 sub-counties, and was also expanded to 54 additional sub-counties in the trailblazing districts. From 2003/2004 to 2004/2005, NAADS expanded into 13 new districts (Hoima, Kamuli, Mbale, Nakapiripit, Rakai, Apac, Kanungu, Kumi, Masaka, Moyo, 3 Rukungiri, Yumbe and Bugiri), bringing NAADS coverage to a total of 29 districts and 280 sub-counties (NAADS Secretariat, 2005; Benin et al., 2007).

Available evidence shows that NAADS has expanded since 2001 and has helped to strengthen the institutional capacity and human resource skills of many farmers to potentially demand and manage the delivery of agricultural advisory services (Benin et al., 2007). For instance, by the end of the 2006/07 financial year, the NAADS programme had been extended to 545 sub-counties (about 83.1% of the total sub-counties in Uganda at the time), and about 40,000 farmer groups and 716,000 individual farmers (representing about 20% of national farming households) had reportedly received services offered by the programme (NAADS, 2007. The programme had contracted about 1,622 private-sector agencies to provide various specialized services to more than 40 enterprises, and about 2,516 community-based facilitators (CBFs) had been trained to provide follow-up services (see Benin et al., 2011). Currently, NAADS covers the whole country.

The philosophical underpinning of the NAADS design is the need to empower farmers. It is grounded in the overarching government policy of decentralization (MAAIF, 2000). NAADS was established with the mandate of increasing farmers' access to information, knowledge and improved agricultural technologies through the overhaul of the extension services delivery system from a supply-driven to a demand-driven service. Other areas of NAADS intervention to support farmer productivity and participation in the market included support to the formation of farmer groups and savings and credit cooperatives (Okoboi, 2011).

NAADS is operated through a number of institutions defined under the NAADS Act of June 2001, involving farmer organizations; local governments; private sector participants; NGOs; a board of directors; a secretariat; the Ministry of Finance, Planning and Economic Development (MFPED); and the Ministry of Agriculture Animal Industry and Fisheries (MAAIF). The NAADS Secretariat works with programme coordinators at the district and sub-county levels and with farmer groups to contract and supervise private professional firms to provide specialized advisory services according to farmers' priority enterprises and needs. In addition, there are CBFs, who are farmers trained to provide quick follow-up advisory services according to farmers' needs (Benin et al., 2011).

Although the NAADS programme is a public investment intervention, a great deal of the responsibility for bringing about agriculture change rests with farmers who have to decide whether to participate in the programme or not. According to Benin et al. (2011), when a farmer decides to participate, he or she has to do so through membership of a NAADS-participating farmer group. Then, together with the members of the group, as well as with members of other NAADS-participating groups in the sub-county, they request specific technologies and advisory services associated with their prioritized enterprises. They also obtain grants for procuring the technologies and related advisory services. The grant is initially used to finance the establishment of a technology development site (TDS), which becomes the source of knowledge and skills development for farmers. It is only farmers that belong to a NAADS-participating farmer group that can access the programme grants. The proceeds from the TDS, whether in kind or cash from sale of output, are used as a revolving fund for members of the group. This is the channel through which the programme is expected to generate its direct benefits. However, the TDSs, service providers, and CBFs are accessible as sources of information to all farmers in the sub-county, irrespective of a farmer's membership of a NAADS-participating farmer group. This is how the programme is expected to generate indirect or spillover effects (Benin et al., 2011; NAADS, 2005). Given this arrangement of extension provision and access in Uganda, it is important to use a definition of extension that encompasses various sources of extension services when modelling extension impacts on productivity.

The current provision of agricultural extension services in Uganda under NAADS, as described above, reflects a change in extension ideology away from the linear model of "top-down" technology transfer, to extension methodologies that emphasize information flows, adult learning principles and participation by stakeholders (Marsh and Pannell, 2000). Under the new paradigm, it is seen as appropriate that farmers should have more control over the information that they need or want and over the way it is delivered. It is held that extension should be "demand-pull" rather "science-push". Therefore, the increased use of farmer groups for agricultural extension is associated with the new paradigm. Extension workers in this case act as facilitators rather than as experts in agricultural science and technology. Available evidence shows that if group-based extension is done well, it holds a number of benefits because of its emphasis on adult learning principles and encouragement of farmer ownership of both problems and solutions (Marsh and Pannell, 2000; Woods et al., 1993).

The dominance of group-based approaches in agricultural extension in Uganda under the NAADS programme raises many issues. Despite the positive outcomes of NAADS, such as high group membership and training received in several areas, use of improved technologies, market output, and wealth status of farmers, concerns about productivity gains are high (Benin). It is important to rigorously assess the impact of the extension services and evaluate the productivity benefits of extension service provision.

2.2 Empirical literature

The strong relationship between higher agricultural productivity and poverty reduction is wide-ranging (Datt and Ravallion, 1998; Salami et al., 2010). For instance, agricultural productivity benefits farmers through increased production and the creation of employment opportunities or, indirectly, by boosting their relative wages or reducing food prices. However, agricultural production and productivity in many developing economies is undermined by many challenges. Extension services are important in these circumstances as they can act as levers to change existing behaviour in the wider agricultural and rural sectors (Cawley et al., 2015). Anderson (2007) defines the terms agricultural extension and advisory services as "the entire set of organizations that support and facilitate people engaged in agricultural production to solve problems and to obtain information, skills and technologies to improve their livelihoods" (Waddington et al., 2010). In its broadest sense, extension is an educational process with communication as its core component. The authors Van den Ban and Hawkins (1996) define the term extension as the conscious use of communication of information to help people form sound opinions and make good decisions. Moris (1991) defined extension as the mechanism for information and technology delivery to farmers. A more comprehensive definition of extension services is given by the World Bank as a "process that helps farmers become aware of improved technologies and adopt them in order to improve their efficiency, income and welfare" (Awulachew et al, 2011).

In developing countries, there is a belief that investment in extension services has the potential to improve agriculture and increase farmers' incomes (Anderson and Feder, 2004). It is not surprising that enormous investment, funding and policy reforms have been directed at agricultural extension in many of these countries. While there is considerable interest and efforts to understand the issues related to agricultural extension in developing countries, and there is a growing literature on this, rigorous impact evaluations of agricultural extension interventions are less common (Anderson and Feder, 2004). Impact evaluation faces a wide range of difficulties, including how to control for factors that influence agricultural outcomes such as agro-ecological climate, weather events, availability and prices of inputs, market access, and farmers' characteristics, among other things. Furthermore, any impact evaluation of extension impact is undermined by a number of inherent methodological challenges such as endogenous placement bias, selection bias and heterogeneity issues related to farm characteristics (see Birkhaeuser et al., 1991; Owens et al., 2001; Anderson and Feder, 2004; Cerdán-Infantes et al., 2008; Betz, 2009).

The empirical literature on the productivity effects of agricultural extension services from a number of studies is not conclusive. For instance, Betz (2009) noted that previous studies on productivity effects of agricultural extension had varying results. The mixed results regarding the impact of agricultural extension on productivity is a consequence of how the methodological issues of endogeneity, heterogeneity and measurement of productivity variable are addressed. Literature on productivity and agriculture extension reveals a number of methodological challenges that make it difficult to make broad generalizations about the productivity effects of agricultural extension services (Odhiambo and Nyangito, 2003; Betz, 2009; Anderson and Feder, 2004; World Bank, 2011). For example, the available empirical research on the effect of agricultural extension services shows large positive rates of return on extension services (Cerdán-Infantes et al., 2008). However, in the absence of random assignment to treatment and control groups, this methodology is likely to provide biased estimates of causal effects, due to the endogeneity of programme participation and the presence of unobservable characteristics that might determine participation and be correlated with the outcome variable (see, for example, Betz, 2009; Cerdán-Infantes et al., 2008; Dercon et al., 2008; Owens et al., 2001).

Besides, Evenson and Mwabu, (1998) argued that previous studies on extension effects of farm yields have ignored an important policy issue, which is that farmers may be affected differently by extension service due to their unobserved personal endowments such as cognitive and physical abilities. Evenson and Mwabu's study addresses this issue using quintile regression, although without controlling for the endogeneity problem. However, using either the meta-production function or the total productivity index, previous studies that addressed the relationship between agricultural productivity and extension services have mainly used the traditional OLS and IV approaches, propensity matching scores (PMS), quintile regression, and treatment analysis. Both OLS and IV are designed to estimate the mean or average causal effect of agricultural extension on productivity. This provides the researcher with an estimate of how efficient an improvement in access to agricultural extension workers is at boosting the production of the average farmer. There is enough evidence to suggest that the use of OLS fails to account for the heterogeneity in the effect of agricultural extension services on farm output, as well as the bias introduced due to the endogeneity of agricultural extension services. Therefore, the widely used strategy to address the selection bias and identify heterogeneous treatment effects has been instrumental variable estimation (Xie et al., 2011; Heckman et al., 2006). This procedure involves identifying a variable that affects assignment to treatment exogenously, but affects the outcome only directly through treatment. The use of the IV approach, however, has practical difficulty in identifying heterogeneous treatment effects and these have motivated the development of other statistical tools.

The propensity score matching (PSM) method, a quasi-experimental method, is applied when it is possible to create a matched sample of treatment and control group to which the difference-in-differences method and the two-stage regression methods are applied. Recent impact evaluation studies that take into account the endogeneity issues use the double-difference (DD) method combined with other methods to deal with the initial conditions that affect the trajectory of impacts. Typically, the PSM is used to select programme participants and nonparticipants who are as similar as possible in terms of observable characteristics that are expected to affect participation in the programme as well as the outcomes. Thus, the difference in the value of the outcome indicator, such productivity or income between the two matched groups, is interpreted as the impact of the programme on the participants (see Benin et al., 2011).

Quantile regression methods have been used to achieve a more complete picture of the agricultural extension effect, because it allows the researcher to estimate the marginal effect of agricultural extension at different points in the conditional production distribution. This approach has an advantage over the traditional ordinary least squares method as it does not assume a constant effect of the explanatory variables over the entire distribution of the dependent variable. Evenson and Mwabu (1998) used the quantile regression technique, and the results revealed that extension services had a discernible impact on productivity and that the impact was at the highest end of the distribution of yields residuals, "suggesting that productivity gains from agricultural extension may be enhancing unobserved productive attributes of farmers such as managerial abilities. The implication of this finding is that other factors such as farm management abilities and experience affect the effectiveness of extension as a determinant of agricultural productivity" (Odhiambo and Nyangito, 2003).

Notwithstanding the above, the development of statistical methods to better understand and accommodate potential biases has been a major methodological achievement of modern quantitative microeconomic analysis. However, only a few studies have effectively addressed the issues of selection and heterogeneous treatment effects concerns (Xie et al., 2011). Concerning treatment effects literature, and despite the availability of several new user-written Stata commands designed to perform counterfactual causal analysis (i.e. treatreg ; itreatreg; pscore; psmatch2 and recently the ivtreatreg command), to the best of our knowledge no study in the area of agricultural extension has applied the new user-written Stata routine called ivtreatreg for the estimation of binary treatment models with and without idiosyncratic (or heterogeneous) average treatment effects. The ivtreatreg command provides consistent estimates for average treatment effect (ATE), the average treatment effect on treated (ATET) and the average treatment effect on non-treated (ATENT), as well as estimates of these parameters conditional on the observable factors x, i.e., ATE(x), ATET(x) and ATENT(x). Myers et al. (2012) have argued that to effectively evaluate the treatment effects, the three treatment effects, namely: (1) ATE; (2) ATET and (3) ATENT (Myers et al., 2012) need to be defined and estimated. The ivtreatreg command is gaining momentum as an econometric tool in addressing endogenous selection bias and numerous studies have made use of it, except in estimating extension impact (see, for example, Ni, 2015; Akotey, 2015; Sneyers and Vandeplas, 2013; Cerulli and Mario De Marchi, 2013).

In conclusion, it should be noted that whereas numerous researchers have acknowledged that mixed results of the impact extension services on farming outcomes are due to endogeneity and selection bias and that these problems can be addressed through an instrumental approach, few studies have been conducted. Therefore, the key contribution of this study is estimating the impact of extension access on farm productivity while controlling for selection and endogenous bias associated with extension access.

3.0 Methodology

3.1 Analytical framework

The analytical framework used is developed within the conventional potential (latent) outcome framework (see Heckman and Robb, 1986; Chernozhukov and Hansen, 2005). Potential real-valued outcomes (Yd) that vary among individuals or observational units are indexed against potential treatment states. The potential outcomes {Yd} are latent, because, given the selected treatment D, the observed outcome for each individual or observational unit is only one component Y ≡ YD.

From a statistical point of view, agriculture extension is considered to be a policy intervention in a "non-experimental" set-up having a "treatment effect", where the treatment variable D (taking the value 1 for farmers who had contact with extension workers, and 0 for farmers who had no contact with extension workers) is expected to affect output y. In this counterfactual framework, we define the unit i's Treatment Effect (TE) as:

$$TE_i = y_{1i} - y_{0i} \quad \text{........................(1)}$$

where y_{1i} is the crop yield for farmer i who had access to extension services, and y_{0i} is the crop yield for farmer i who had no access to extension services. Therefore, identifying TEi directly is not possible because an individual cannot be observed in both states at a given time; we cannot observe the value of the explanatory variable in both states. For instance, it might be the case that we can observe the production behaviour of a farmer who had accessed agriculture extension services, but we cannot know what the output production of this farmer would have been if this farmer had not accessed extension services, and vice versa. Therefore, we face a fundamental missing observation problem (Holland, 1986) that needs to be overcome to reliably recover the causal effect (Rubin, 1974).

Assuming that d is the treatment binary variable (1=had access to extension services, and 0= no access) and an independent, identically distributed sample of the population, this rules out that a treatment effect on farmer i affects farmer j. Indeed, this assumption is not very restrictive since only a few farmers obtain access to extension services compared to farmers engaged in production in the agricultural economy. Thus the treatment effect is given by $y_1 - y_0$. Since (y_1; y_0; d) is a vector of random variables, then $y_1 - y_0$ is random too. According to Rosenbaum and Rubin (1983), the first step to estimate treatment is to compute the ATE[1].

We have the following equations:

$$y = y_1 d + y_0 (1-d)$$
$$y = x\beta + \alpha d + \varepsilon \quad \text{(2)}$$

However, the selection into an extension programme is not observed and therefore treatment is endogenously defined because of selection bias. In econometric terms, this implies the residuals of the models are not independent of the treatment. For instance, if farmers (productive farmers) with the highest unobserved preference for extension services choose to participate in agricultural extension programmes more than farmers with a lower unobserved extension propensity, then access to extension services is correlated with cognitive and physical ability, which causes dependence between error term and treatment variable. Waddington et al. (2010) argued that as far as agricultural extension is concerned, selection bias occurs where skilled and knowledgeable farmers are more likely to seek out extension services and, although this source of bias may be reduced if extension agents initiate contact with the farmers, agents themselves may also prefer to work with more experienced farmers (see also Owens et al., 2001). Furthermore, simultaneity bias arises in the sample of farmers visited by extension services if farmers only contact extension agents when they have problems. Evidence from many African countries shows that the extension contact variable is endogenous since most of the extension contacts are farmer initiated. Nonetheless, extension services staff select farmers based on certain characteristics such as performance and size, which means that some farmers are visited more frequently than others (Birkhaeuser et al., 1991). The remedy to this problem has been mainly solved by the IV approach. However, the application of IV requires the availability of at least one variable, z, called the "instrumental variable", which is assumed to have the following two properties:

(1) z is (directly) correlated with treatment d

(2) z is (directly) uncorrelated with outcome y.

These are conditions of relevance and exogeneity (Wooldridge, 2009; Arabsheibani and Staneva, 2012). The relevance condition requires that the instrument be correlated with the endogenous variable (agricultural extension), and the exogeneity condition requires that the instrument affects production only through the channel of agricultural extension, and therefore the instrument is uncorrelated with the error term in the production equation.

1 In this study, the ATE reveals how the mean outcome would differ if all eligible farming households who had access to extension services versus the mean outcome if all eligible farming households had no extension access.

Extension agents are some of the most important sources of agricultural information in any country. Extension services include transferring knowledge to farmers, advising on and educating farmers in their decision making, enabling farmers to clarify their own goals and possibilities, and stimulating desirable agricultural developments. Farmers' exposure to such information as a result of extension contact reduces subjective uncertainty and therefore increases the likelihood of the adoption of new technologies. This means that agricultural extension contact is non-formal education that serves to transmit specific information needed for farming tasks (Weir, 1999). Feder et al. (1987) have argued that the training of farmers pays, and that farmer education can help even without new technologies. According to James et al. (2009), the information farmers obtain from the extension services enhances human capital and may be characterized as a production input, in the same way as land and labour. It is argued by Schultz (1975) that agriculture-specific human capital improves farm yields and enhances the resource allocation abilities of farmers (Evenson and Mwabu, 1998). Therefore, the impact of agricultural extension services on productive efficiency can be evaluated through its marginal product, where extension is considered a factor of production, or a factor explaining individual technical efficiency measures (see Kaliba and Engle, 2004).

This implies that the impact of extension services on farm productivity can be measured through output gain due to the elimination of technical inefficiency. Thus, if we assume agricultural extension contact is a form of education (non-formal farmer education), there are four possible effects of extension contact: the worker effect, the allocative effect, the innovative effect and the external effect (see Weir, 1999). However, data at the household level can reveal only direct (worker) effects of schooling (extension contact) on output. Therefore, this study focussed only on the worker effect of extension contact. The worker effect of schooling refers to the increase in farm output that directly relates to education, holding other inputs constant. For instance, one major reason why farmers are technically inefficient is ignorance of best practices. Cognitive and non-cognitive skills attained as a result of extension contact may increase technical efficiency of farmers. Kalirajan and Shand (1985) argued that an illiterate farmer without formal training can understand modern production technology as well as his educated counterpart, provided the technology is communicated properly. Therefore, based on the hypothesis that human capital acquired through schooling or via extension advice enhances productivity of farmers (Schultz, 1975), we assume that access to agricultural extension services is associated with higher output, ceteris paribus. The following productivity equation is specified for a given household i:[2]

$$Yield_i = f(D_i, X_i) \qquad (3)$$

where Yield is the value of agricultural output per acre for household I, D is a variable that captures agricultural extension access, and X is a vector of exogenous variables

2 The i^{th} subscript is dropped henceforth.

that relates to agricultural inputs (capital, labour and technology). The variables include age of household head, labour force supply (both family and hired labour), household head schooling and land size. Dummies for gender of the household head, use of organic and inorganic fertilizers and receiving remittances, livestock ownership, agro-ecological dummies and crop types are included in the equation. The dummies for agro-ecological zones and crop types were included in the model to proxy soil quality and control for effects of crop-specific factors on farm yields (Evenson and Mwabu, 1998). The current data was collected from nine (9) Public Zonal Agricultural Research and Development Institutes (ZARDIs) agro-ecological zones. The 9 ZARDIs are described in Appendix 1.

3.2 Empirical estimation

The agricultural extension services under study were not randomized. Households were free to either access or reject extension services. The option to choose creates room for self-selection and endogeneity bias. Since selection bias and endogeneity problems can cloud effective impact assessment, we resolved this by employing the ivtreatreg Stata command that caters for selection bias and the endogeneity problem simultaneously in empirical analysis. By using the ivtreatreg command, a choice has to be made to either use the Heckman sample selection or treatment effects model, or instrumental variable modelling. Since the demand for extension services is not only influenced by observed factors, but also by unobserved factors, the Heckman or treatment effects models may be inappropriate. We therefore adopted the instrumental variable model that takes into account the unobserved variables and also controls for the endogeneity bias. The instrumental variable approach requires an observed variable that is (1) highly correlated with the demand for agricultural extension services, but (2) uncorrelated with the unobserved factors influencing household crop productivity. The assumptions of the IV model referred to as "exclusion restriction" by Khandker et al. (2010: 88) are summarized as:

$correlated\ with$ extension access: cov (Z,extension access) ≠0

$uncorrelated\ with\ error\ term$ (ε):cov (Z,ε)=0

where Z is the chosen instrument. Although numerous studies on agricultural extension have used instrumental variables, finding a variable correlated with the participation in extension programmes but not with the studied outcome is not an easy task since by programme design the criteria used to select farmers for extension services are usually correlated with the outcome (Cerdán-Infantes et al., 2008). For instance, Akobundu et al. (2004) used distance from the extension office, whether an individual was rejected for a loan, total farm debt, and the previous visit of an extension agent (not from the programme). In this study, membership of a farmer group was used as an instrument. The instrument has satisfied the relevance and exogeneity conditions. Like in other studies, farmer group membership has been found to significantly associate with the probability of participating in agricultural extension programmes however it's relationship with out per acre is not significant

(Hasan et al., 2013; Bindlish et al., 1993; Muwonge 2007; Benin et al., 2007; Betz, 2011). Nonetheless, intuitively using membership to farmer group as instrument is expected to affect the decision to participate in extension services independent of farmer personal characteristics and/or farm performance.

Notwithstanding the above, it has been argued that the most efficient instrument is the predicted probability of getting treatment, comprising the selected instrument(s) plus the other exogenous (control) variables influencing the outcome variable (see Wooldridge, 2009; Cerulli, 2011; Akotey, 2015). According to Cerulli (2011), the predicted probability of getting treatment (derived by regressing extension access on xi and zi) is the best instrument because it generates the smallest projection error. The estimation procedure we adopted follows this estimation strategy under the IV approach.

Under the IV approach within the ivtreatreg command estimation options, different estimation models have been designed to evaluate programme impact. These include the IV-probit, direct-2SLS (-stage least squares) and probit-2SLS. The IV-probit is appropriate when the endogenous variable is continuous, and therefore not appropriate for estimating a model with a discrete endogenous variable. The direct-2SLS is also not appropriate because it is designed for the estimation of linear regression (Akotey, 2015). We thus adopted the probit-2SLS estimation procedure because it fits our binary extension access endogenous variable. First, we estimated a probit model of extension contact on exogenous factors and instrument (membership to farmer group) to derive the predicted probability of extension access. Second, we used the predicted probabilities as instruments of extension contact to estimate the 2SLS model. This approach is known to yield consistent estimates and is also more efficient than the direct-2SLS (Cerulli, 2012, Akotey, 2015). This empirical approach is now considered to be an attractive alternative to PSM[3] in overcoming the well-known methodological challenges associated with endogenous selection. The probit-2SLS also allows for the determination of homogenous and heterogeneous treatments outcomes. It is thus very appropriate for this study.

Nonetheless, although educational attainment in Equation 3 is a predetermined variable, endogeneity may exist if investments in education made many years ago were correlated with unobserved variables which affect productivity today, such as ability and motivation (Strauss and Thomas, 1995). Therefore, variables such as family background have been used to proxy the unobserved ability of the farm decision maker. Although such variables are not available in the ATAAS survey data used in this study, numerous empirical studies have proven that the bias arising from the omission of unobserved ability and motivation is not large (Weir, 1999). Thus, the endogeneity issue associated with years of schooling was not controlled for in this study. To address the heteroskedasticity that may be present, a Huber-White sandwich estimator was used in the regression estimations.

3 According to Cameroon and Trivedi (2005)added, matching methods are proven not to be robust against hidden bias arising from unobserved variables that simultaneously affect assignment to treatment and the outcome variables (Cerulli, 2012).

3.3 Crop productivity measurement

In any empirical studies involving the estimation of crop yields, the key concerns are related to how to measure crop yields and whether to estimate aggregate crop yields or specific crop yields. In many developing countries, two approaches have been widely used to measure crop yields: crop cut and the farmer recall methods. These involve surveying farmers to obtain their estimates of the total crop they harvested and dividing this by estimates of how much land they planted to calculate estimated yields. Available evidence reveals that both crop-cut and farmer-estimation methods have their own inherent biases and difficulties that may not be easy to solve when it comes to estimating the household farm crop yields. Indeed, numerous studies show that crop cuts gave 14% to 38% higher yield estimates than whole plot reference harvests, while farmer recall estimates overestimated yields by less than 15% (Fermont and Benson, 2011).

However, notwithstanding the challenges associated with the farmer estimation method, empirical evidence is increasingly showing that estimates by farmers do not necessarily result in a larger total error than those obtained using the crop-cut method (Fermont and Benson, 2011; Diskin, 1999). Nonetheless, in many developing countries' agricultural systems, because of mixed cropping (or intercropping) it has proven to be a challenge to measure and interpret data on key specific crop yields because it may not be possible to ascertain the actual land used for specific crops. According to Diskin (1999), mixed cropping takes different forms: one crop may occupy space within the plot that would otherwise be occupied by another; one crop may be added between rows of another crop which has been planted at its normal density; or two crops may share a plot for only a brief part of the growing season or occupy it at entirely different times of the year.

Over 70 per cent of farmers in Uganda practice intercropping as they try to spread risk by diversifying their production and increase the total output of individual fields, (Fermont and Benson, 2011). It is therefore difficult in such situations to accurately measure yields for specific primary crops – resulting in serious underestimating. There are a number of approaches to address this measurement problem arising from intercropping effects. These include: dividing the crop area by the number of crops grown on them or dividing total production of crop X by the whole area planted to both crops. However, these approaches have proved unsatisfactory. For example, if two crops, maize and cassava, are grown together on one acre of land, the area assigned to each crop would be 0.5 acres. In most cases, crops do not share the land equally, which seriously impairs the validity of the first approach. However, the availability of price data that allows the computation of a productivity indicator from weight yield to value yield is one of the appropriate answers to the problem of intercropping. In this study, using actual yield measures per crop when intercropping is practiced would be misleading because individual crop yields will be artificially low (Peterman et al., 2010). Therefore crop productivity model estimations were derived at aggregated crop level.

3.4 Functional form of production function

In estimating production functions, two models are commonly used: the Cobb-Douglas model and the transcendental logarithmic (translog model). The Cobb-Douglas model, although popular, is questioned because of its restrictive assumptions such as homogeneity, separability and elasticity for substitution (Lyu et al., 1984). Compared to the Cobb-Douglas model, the translog function model has a number of advantages. This model adds the effects of interactions between inputs and keeps the structure of the underlying technology as general as possible. In the initial stages of this research, we aimed to adopt the translog form of production function and tobit model. However, translog production estimations violated the monotonicity requirement. The monotonicity requirement is fulfilled if there are positive marginal products with respect to all inputs. During the preliminary analysis of the modified translog production function, the first order parameters (marginal products) of key inputs were negative. Therefore, the monotonicity requirement was not fulfilled. We adopted a double log-linear model specification over a linear specification because the positive variables (yield, land, labour and age) were skewed. Thus the dependent variable and positive independent variables were transformed using their natural logarithms to remove the influence of outliers in the sample, to smooth the distribution of the data and to interpret our coefficients as percentages. From a practical point of view, taking logs for positive variables can mitigate or eliminate conditional distribution problems due to heteroskedasticity or skewedness (Wooldridge, 2009). A double log-functional form (Equation 4) was therefore estimated as this specification has appealing attributes:[4]

$$\ln[Yield] = \beta_0 + \beta_1 EXT\_access + \beta_2 Inage + \beta_3 Inage\_sq + \beta_4 Inlabour + \beta_5 Land + \beta_6 Land\_sq + \beta_7 D_1 + \beta_8 D_2 + \beta_9 D_3 + \beta_{10} D_4 + \beta_{11} D_5 + \beta_{12} D_6 + \beta_{13} D_7 + \beta_{14} D_8 + \varepsilon \quad \text{......} 4$$

where $\beta_0 - \beta_{14}$ are parameters to be estimated and ε is an error term assumed to be independently, identically, and normally distributed with zero mean and constant variance. The dependent and independent variables are described in Table 1.

4 According to Wooldridge (2009, p. 191), using natural logs has many appealing attributes explaining its wide use in most empirical research.

Table 1: Description of variables

Variable	Description
Ln (Yield)	Logarithm of yield per acre for household i
EXT	Access to extension services (1 if yes, 0 otherwise)
Age	Age of household head in complete years
Age squared	Age of household head in complete years squared
Labour	Total household labour in persons (hired and family labour)
Labour_sq	Total household labour in persons (hired and family labour)
Land	Total land area owned by household in acres
Land_sq	Total land area owned by household in acres squared
D1	Household head's education dummy (0= no primary, 1= primary, 2 secondary , 3 post-secondary)
D2	Dummy for gender of household head (1=male, 2=female)
D3	Dummy for organic fertilizer use (1 if yes, 0 otherwise)
D4	Dummy for inorganic fertilizer use (1 if yes, 0 otherwise)
D5	Dummy for receiving remittances (1 if yes, 0 otherwise)
D6	Dummy for livestock ownership (1 if yes, 0 otherwise)
D7	Dummy for agro-ecological zones (1=Abi, 2=Buginyanya, 3=Bulindi, 4=Kachwekano, 5=Mukono, 6= Ngetta, 7=Nabuin, 8=Mbarara and 9=Rwebitaba)
D8	Dummy for crop-specific factors (1=Bananas, 2=Beans, 3=Cassava, 4=Coffee, 5=Peas, 6=Potatoes, 7=G/nuts, 8=Maize, 9=Sorghum, 10=Simsim, 11=Millet, 12=Rice and 13=Other crops)

3.5 Data and source

The data used were drawn from the baseline survey of ATAAS 2013 that covered all 112 districts in Uganda. The survey household module collected information on household characteristics, which included: housing conditions, household incomes; production and value-added assets. In relation to agriculture, information was collected on household land holdings and characteristics of the land holding; agronomic and soil fertility management practices, livestock enterprises, marketing information and access to agricultural extension services. The module also covered individual characteristics of household members, including demographics. The survey was administered by the Ugandan Bureau of Statistics (UBoS). A two-stage stratified sampling design was used to select a total of 11,881 households. At the first stage, enumeration areas (EAs) were grouped by agro-ecological zones (ZARDI) and rural-urban location, and then selected using probability proportional to size (PPS). At the second stage households, which are the ultimate sampling units, were selected using systematic random sampling. A total of 900 EAs were selected using the 2012 Uganda Population and Housing Census Mapping Frame. These EAs were distributed to the 9 ZARDI agro-ecological zones in equal proportions, with consideration of the rural-urban divide (NAADS, 2015).

3.5 Specification tests

To obtain a robust estimate of the effect of extension contact on aggregate crop productivity, we account for potential bias from several sources. The first concern is that access to extension services is endogenous and we thus adopted an instrumental variable estimation to tackle the endogeneity problem. Specifically we employed the most efficient variant of IV estimators, the probit-2SLS framework (Cerulli, 2011). The effectiveness of the IV approach depends on the validity of the proposed instrument by checking its relevance and exogeneity with respect to the outcome variable. To ascertain the relevance of membership of a farmer group, we estimated a probit model of extension access against membership of a farmer group. The probit results are presented in Appendix 2. The instrument (membership of a farmer group) is positive and statistically significant at the 5% level, indicating that farmers who are members of a farmer group were more likely to receive agricultural extension services than their counterparts. The instrument seems to be relevant, as it can by itself explain 8% of the variation in the treatment variable. By adding household factors, we test the possibility that the relevance of the instrument is not affected by the inclusion of factors that could affect both changes in extension access and farm productivity. This seems to be the case, as the magnitude and significance of the point estimates associated with the extension access are barely affected by the inclusion of household control factors.

3.6 Characteristics of sampled households

Table 2 presents the summary statistics of the variables used in the analysis. The summary statistics are disaggregated by household access to extension services. The last column of Table 2 presents the chi-square test and t-test results on the degree of difference between households in the sample who accessed extension services and those who did not. Data on access to extension services revealed that 60.8% of households in the sample had access to extension services. The t-test indicates that households who had access to extension services do significantly differ from those who did not access extension services in terms of output harvested, land size and labour used in production. However, we did not find significant differences with respect to age of the household head. Conversely, the chi-square test results indicate that households who had extension contact do significantly differ from those who did not in respect of education levels, gender, use of inorganic fertilizers, remittances received and livestock ownership. The descriptive summaries for crop type and agro-ecological zones dummies were also significantly different by extension access.

Table 2: Household level summary statistics

Variable	Received extension services (%)	Not received extension services (%)	**Chi-square (χ2.050)**
Output harvested in kg (mean)	1646.9	1301.4	-345.5 (0.08)T**
Land ownership in acres	2.68	2.01	-0.67 (0.000)T*
Labour in persons (family and hired labour)	3.54	3.13	-0.41 (0.000)T*
Age of household head in years	44.4	43.9	-0.43 (0.162)T
Education level			
No education	19.2	28.1	
Primary	53.9	52.8	156.8 (0.000)*
Secondary	19.2	13.9	
Post-secondary	7.8	5.2	
Gender of household head			
Male	75.2	73.4	4.34 (0.037)*
Female	24.9	26.7	
Organic fertilizer use			
Yes	90.2	89.9	0.23 (0.631)
No	9.9	10.1	
Inorganic fertilizer use			
Yes	96.3	97.3	7.85 (0.005)*
No	3.7	2.7	
Received remittances			
Yes	45.2	33.8	137.6 (0.000)*
No	54.8	66.2	
Marital status			
Married	27.5	28.9	2.37 (0.124)
Unmarried	72.5	71.1	
Own livestock			
Yes	68.2	56.2	158.7 (0.000)*
No	31.9	43.9	

Note: ** and * indicate 10% and 5% significance levels, respectively; T indicates t-test instead of chi-square.

4.0 Empirical Results

Given that OLS estimation is expected to bias the results due to endogenous selection problems, the results of interest are those from the probit-2SLS IV approach. However, the OLS estimates are also presented in Table 3 to illustrate the scale of the difference between both estimation methods when endogenous selection bias is addressed. The results show that access to extension services does have a negative and statistically significant effect on farmer productivity controlling for various household characteristics. This is a rather unexpected result because from the literature, access to agricultural extension services is expected to have a positive effect on farm productivity. Evidence from other studies indicate that if the sample is sufficiently selective of the population, as is the case with current agricultural extension participation, the bias may be large enough to reverse the sign on the estimated effect, producing a negative estimate for a causal effect that should in fact be positive (see Elwert and Winship, 2014). Employing the ivtreatreg Stata command to generate the endogenous treatment results using probit-2SLS,[5] the extension access variable becomes positive, although is not statistically significant. These results suggest that the impact of agricultural extension access on farm productivity is insignificant once endogenous selection bias is accounted for. This finding reinforces numerous arguments in the extension literature that selection and endogeneity problems can distort the actual impact of extension contact and therefore the need to account for these bias issues.

Nevertheless, we offer the following explanations for the insignificant impact of access to agricultural extension services observed for IV results. First, it may be that access to extension services is not sufficient enough to translate into increased productivity. It should be noted that the worker effect of extension contact may be considered to be a lower bound for the full effect of extension contact on farm productivity, since part of the effect of extension access is its role in the allocation of other inputs into production and these inputs have been controlled for a priori in model estimation. Another possible explanation is recent evidence from Uganda and Ethiopia that shows that it is the quality of extension services that matters for farmer productivity, rather than the frequency of extension visits (Ragasa et al., 2012, Okoboi et al., 2013). Okoboi et al. indicate that although the NAADS programme has had a

5 We used a Stata module called IVTREATREG to estimate the treatment effects with selection and heterogeneity, which is available at http://ideas.repec.org/c/boc/bocode/s457405.html

remarkable impact on access to extension services, the quality of extension services is still poor, particularly in relation to the incompetence of extension providers.

In addition, much of the extension service efforts in Uganda, including the NAADS service provision, focuses on input delivery and persuading farmers to adopt new technologies, crop varieties, and to market produce and seek credit facilities. Therefore, beyond the influence of visits or advice by extension agents, there is no other direct effect on productivity. Recent evidence from NAADS has shown that direct participation in the NAADS programme did not have any statistically significant effect on the adoption of new crop and livestock enterprises and the improved agricultural technologies and practices considered, except in the case of recommended planting and spacing practices, where it was associated with greater use, but only when compared with non-participation in areas where the programme had never been implemented (Benin et al., 2011).

The effects of the other regressors on farm productivity are also of interest. The productivity response to land is statistically significant and has a U-shape. The negative coefficient of household land size implies that larger land sizes are associated with low output per acre, by 30%. Similar conclusions have been reached in Uganda about land by Betz (2011), who found that a 1% increase in land size decreases value of output per acre by 0.38%. There are also numerous studies elsewhere that have confirmed this inverse relationship between land size and productivity. Ali and Deininger (2013) have noted that many studies found that agricultural production is characterized by constant economies of scale, implying that a wide range of farm sizes can coexist. However, the square of land has a positive significant effect on productivity, indicating a U-shape relationship between agricultural crop productivity and land size. That is, agricultural crop productivity first decreases with land size, then increases after a given threshold. This implies that below this threshold, small farmers are more productive, and beyond this level productivity increases with land size. The argument for small farms being more productive is that they make greater use per acre of traditional variable inputs such as human labour and fertilizers. It is the relative intensity of the use of these inputs on small farms that is attributed to their higher land productivity. This is particularly an interesting finding from the point of view of poverty reduction through agriculture.

The use of fertilizers has been proven to be important drivers of agricultural productivity among farmers in sub-Saharan Africa. The coefficients on use of organic and inorganic fertilizers are positive and statistically significant. This shows that households who use both organic and inorganic fertilizers are 11% and 17% more productive, respectively, than those who did not use fertilizers.

With respect to agro-ecological zones, there are differences in crop yield across zones, with yields being generally higher in the Abi zone than in the Buginyanya, Ngetta, Nabuin and Rwebataba zones. These significant findings on ecological zones reinforces the relevance of agro-ecological factors, which include soil quality and rainfall variability driving farm productivity. The results of the effects of crop-specific factors on yields reveal that farm yields are higher for bananas/matooke than for any other crop.

Table 3: OLS and IV results

Log of yield	OLS results		IV results (probit-2SLS)	
	Coef.	Robust Std. Err.	Coef.	Robust Std. Err.
Extension access	-0.066*	0.023	0.055	0.085
Log of age of Household head	-0.071	0.459	-0.117	0.486
Log of total labour	0.069*	0.020	0.025	0.060
Log of land	-0.307*	0.014	-0.300*	0.039
Log of age squared	0.004	0.062	0.028	0.067
Log of land squared	0.055*	0.008	0.055*	0.008
Educational level (base category: no education)				
HHeduc_primary	0.074*	0.029	0.054	0.083
HHeduc_secondary	0.079*	0.037	0.035	0.114
HHeduc_post_secondary	0.087**	0.049	-0.094	0.148
HHgender_male	0.096*	0.026	0.128	0.082
Use of organic fertilizers	0.111*	0.040	0.108*	0.040
Use of inorganic fertilizers	0.199*	0.064	0.186*	0.065
Received remittances	-0.041**	0.024	0.088	0.088
Own livestock	0.093*	0.024	-0.008	0.070
Agro-ecological zones (base category: Abi)				
Buginyanya	-0.388*	0.044	-0.330*	0.052
Bulindi	0.154*	0.048	0.158*	0.049
Kachwekano	0.053	0.076	0.084	0.078
Mukono	0.054	0.048	0.063	0.049
Ngetta	-0.248*	0.047	-0.222*	0.049
Nabuin	-0.642*	0.047	-0.629*	0.051
Mbarara	-0.026	0.054	-0.011	0.055
Rwebitaba	-0.130*	0.058	-0.099**	0.059
Crop type (base category: bananas/matooke)				
Beans	-0.337*	0.032	-0.340*	0.032
Cassava	-0.330*	0.036	-0.333*	0.037
Coffee	-0.551*	0.071	-0.572*	0.073
Peas	-0.565*	0.117	-0.564*	0.116
Potatoes	-0.400*	0.085	-0.401*	0.085
G/nuts	-0.250*	0.060	-0.254*	0.062
Maize	-0.210*	0.052	-0.215*	0.053
Sorghum	-0.172**	0.094	-0.171**	0.096
Simsim	-0.478*	0.088	-0.456*	0.089
Millet	-0.014	0.077	-0.011**	0.078
Rice	-0.598*	0.161	-0.586*	0.161

Other crops	-0.461*	0.043	-0.454*	0.044
Constant	6.298*	0.842	6.099*	0.900
Number of observations	10730		10730	
R-squared	0.1428		0.1397	

Note: ** and * indicate 10% and 5% significance levels, respectively

In addition to the average treatment effects (ATE) results defined by the agricultural extension access dummy in Table 3 above, our analysis allows for the calculation of another two relevant causal parameters: the average treatment effect of the treated (ATET) and the average treatment effect of the non-treated (ATENT). Table 4 sets out the point results for the ATE, ATET and ATENT. We can immediately observe that the ATET is equal to 0.055, while the ATENT is equal to 0.053. The ATET and ATENT estimates are not far from the ATE estimate.

Table 4: Estimation of treatment effects (ATE , ATET and ATENT)

Variable	Observed coef.	Std.Err.	p-value
ATE	0.055	0.085	0.520
ATET	0.056	0.083	0.503
ATENT	0.053	0.084	0.527

Note: Standard errors for ATET and ATENT are obtained via bootstrapping.

The standard errors for the ATET and ATENT are obtained via bootstrapping, as analytical formulas are not available for these two parameters.[6] After the bootstrap estimates, it evident that both ATENT and ATET are positive and not significant. Table 5 sets out the main characteristics of the distribution of ATE(x), ATET(x) and ATENT(x), respectively.

Table 5: Descriptive statistics for the distribution of ATE(x), ATET(x) and ATENT(x)

Variable	Obs	Mean	Std. Dev.	Min	Max
ATE_x	10730	0.055	0.187	-0.495	0.810
ATET_x	6527	0.056	0.185	-0.476	0.647
ATENT_x	4203	0.053	0.191	-0.495	0.810

The estimates presented in Tables 4 and 5, particularly the signs of the ATET and ATENT coefficients, provide insights into the productivity impact of extension access. The positive sign for ATET(x) means that if farming households who had extension access change their status, thus becoming non-receivers of extension services, they would be less productive compared to their current status (being receivers of extension

6 We used a bootstrap procedure with 100 replications to estimate standard errors for testing ATET and ATENT significance.

services). Therefore, this result suggests that, given a structure which is the same as that of a farmer who received extension services, a farmer who did not receive extension services would have a lower level of farm yields. The positive mean value of the ATENT(x) shows that for farming households who had no extension access and who changed their status, thus becoming receivers of extension services, the level of their farm yields would increase. Therefore, given a structure which is the same as that of a farmer who did not receive extension services, a farmer who receives extension services would have a higher level of farm yields. To understand the implications of these results, one needs to appreciate the fact that a given structure referred to here, agricultural extension receivers and non-receivers, depends on the farm characteristics contained in the vector x. This implies that the effect of extension access on farm productivity is not void of relevant discriminating factors characterizing the differential structure of farms that receive and those who do not receive extension services. This suggests that the impact of extension services on farm productivity mainly depend on the role played by other relevant distinguishing factors of the farmer. This relates to the fact that farmers may benefit differently from extension services depending on their idiosyncratic characteristics. For instance, a risk averse farmer may benefit more than a less risk averse one, since a more risk averse farmer is less likely to adopt new technology (see Awely and Azomahou, 2014).

5.0 Conclusions

From a theoretical and practical point of view, providing agricultural extension services is considered to be an effective avenue to contribute to the growth of the agricultural sector and poverty reduction in developing economies like Uganda. Resources have been channelled into reforming and extending extension services to many farmers in developing economies through various interventions. However, there is a dearth of robust impact assessments to support more investment committed into extension service provision. We contribute to the impact evaluation literature on extension contact by providing evidence from comprehensive baseline survey data collected for monitoring and evaluation of the ATAAS project.

The findings of the study provide insight into understanding the productivity impact of access to extension services, and lead to important policy conclusions for improving agriculture growth and productivity, which in turn contributes to poverty reduction and development in Uganda. The estimation results suggest that the impact of extension services on farm productivity is positive, but insignificant once selection of unobservables is controlled. This is in contrast to previous works on extension impact that found a significant positive impact of access to extension on farm level outcomes. The findings of these studies may be prone to selection and endogenous bias associated with extension contact variable.

Nonetheless, the insignificant positive results of access to extension services reflect that access to the current extension services does not translate into significant positive effects on farm productivity for reasons related to the weakness of Uganda's extension service system. Numerous critics have argued that the quality of Uganda's extension services rendered by extension providers and agents is poor and unlikely to translate into positive significant impact on farm output. Indeed, recent research has questioned the quality of extension services in Uganda, particularly NAADS (Benin et al., 2011; Okoboi et al., 2013). This finding demonstrates that for extension services to achieve the intended objective of transforming farmers into a productive workforce, the quality of extension services provided is paramount.

From a policy perspective, the study's results on ATET and ATENT demonstrated that farmers benefit differently from extension services, depending on their relevant distinguishing factors characterizing the differential structure of farming households. These factors govern the structures within which different farmers find themselves and may include factors such as risk aversion of farmers, scale and location specific factors. In this regard, interventions to promote extension services to farmers such as NAADS should be complemented with dynamic measures that support the growth and productivity of farmers in general.

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Appendix 1: ZARDI agro-ecological zones

Abi	Arua, Nebbi, Moyo, Adjumani, Koboko, Yumbe, Maracha-Terego and Zombo
Buginyanya	Sironko, Mbale, Iganga, Jinja, Tororo, Mayuge, Namutumba, Namayingo, Luuka, Kamuli, Kaliro, Buyende, Bugiri, Pallisa, Kibuku, ButalejaBusia, Budaka, Manafwa, Kween, Kapchorwa, Bulambuli, Bukwo and Bududa
Bulindi	Hoima, Masindi, Kiryandongo, Kibaale, and Buliisa
Kachwekano	Kabale, Rukungiri, Kanunugu and Kisoro
Mukono	Mukono, Mpigi, Kayunga, Kalangala, Kampala, Luwero, Masaka, Nakasongola, Mubende, Wakiso, Nakseke, Buikwe, Buvuma, Mityana, Kiboga, Kyankwanzi, Gombe, Kalungu, Bukomansimbi, Butambala and Lwengo
Ngetta	Lira, Apac, Dokolo, Lamwo, Nwoya, Agago, Albetong, Amolatar, Kole, Otuke, Oyam, Pader, Kitgum, Amuru and Gulu
Nabuin	Moroto, Nakapiripirit, Kotido, Kumi, Bukedea, Serere, Amuria, Ngora, Katakwi, Napak, Amudat, Kabono, Soroti, Kaberamaido and Abim
Mbarara	Mbarara, Ntungamo, Bushenyi, Kiruhura, Lyantonde, Sheema, Rubirizi, Mitoma, Isingiro, Ibanda, Buhweju, Sembabule, and Rakai
Rwebitaba	Bundubugyo, Kabarole, Kamwenge, Kasese, Kyegegwa, Kyenjojo and Ntoroko Agricultural

Appendix 2: Probit estimation results

Extension access	Coef.	Std. Err.	Coef.	Std. Err.
farmer_group1	1.205	0.038*	1.182*	0.040
Land			0.007*	0.003
Labour			0.004	0.004
HHeduc_primary			0.242*	0.034
HHeduc_secondary			0.389*	0.045
HHeduc_post_secondary			0.363*	0.062
HHgender_male			0.016	0.033
Urban residence			0.296*	0.045
Age			0.000	0.001
Married			-0.041	0.029
Owned livestock			-0.192*	0.027
Received remittances			0.362*	0.028
Number of obs	10730		10730	
Pseudo R-squared	0.083		0.111	

Note: Constant term included, but not reported. * Significant at 5%.

Mission

To strengthen local capacity for conducting independent, rigorous inquiry into the problems facing the management of economies in sub-Saharan Africa.

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