The Effects of Agricultural Extension Services on Farm Yields in Uganda: Evidence from Agriculture Census Data

By

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Abstract

The present study investigates the productivity effects of agricultural extension services in Uganda drawing upon Uganda Agriculture Census (UCA) data (2008/2009). The descriptive show that 21% of farming households had accessed extension services from public and other providers. The proportion of household who initiated contact extension were only 3% compared to 8% through predetermined visits by extension agents and 10% through both routine and on demand. However, it was revealed that popular information sources among farmers were radio (88%) and fellow farmers (72%). We estimated treatment effect of extension contact using counterfactual framework. Results of the treatment effect model show a significant effect of access to extension services on yield. On average, farming households who had extension contact were more productive than farming households with no extension contact Implementing the *ivtreatreg* stata command that take care of the selection into homogeneous and heterogeneous treatment, we estimated the average treatment effect (ATE), average treatment effects on the treated (ATET) and average treatment effects on the non-treated (ATENT). The ATE had a negative sign meaning that farming households who had extension contact would have been less productive if they had not got access to extension services. The negative average value of ATET (x) implies that farming households who had extension contact would on average produce less than one tonne per acreage if they get more access to extension services, demonstrating diminishing returns associated with more and more extension contacts. The mean value of the ATENT(**x**) predict that on average farming households who had no extension contact would have been more productive if they had extension access. Crop productivity OLS and 2SLS estimates show that extension contact matters for farmer productivity more so if extension contact is initiated by farmer. The study recommends that extension contact has favouarble effect on farmer productivity and therefore efforts should be geared at reforming the extension system to reach the majority of unreached farmers and focus more on empowering farmers to demand extension services themselves.

1.0 Background to study

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 lives in rural areas and their survival directly or indirectly depends on agriculture. In Uganda, 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, in many African countries including Uganda, productivity 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 agriculture 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 a policy agenda for many developing countries in Africa.

In Uganda, there is a strong belief from the government that if all 40 million hectares of arable land in Uganda is put to their full potential, every Ugandan will be out of poverty. For example, in the Comprehensive Africa Agriculture Development Programme (CAADP), Uganda has committed, firstly, to the principle of agriculture-led growth as a main strategy; secondly, to the pursuit of a 6 percent average annual growth rate for the agricultural sector; and thirdly, to increase the share of the national budg*et al*located to the agricultural sector (MAAIF, 2010). The Plan for Modernization of Agriculture (PMA) was implemented to increase the contribution of agriculture in the economy and thus reduce the mass poverty. One of the key components PMA was to improve delivery of agricultural extension through the National Agricultural Advisory Services (NAADS) program (Sebaggala & Okello, 2010; Benin *et al*, 2007). It is not surprising that this component has taken the largest share of total agriculture spending in the recent past. For instance, the overall allocation to agricultural extension has increased from 25% of total sector spending in 2005/06 to nearly 43% in 2009/10 (Lukwago, 2010).

NAADs program was introduce as a response to traditional extension approach that had failed to bring about greater productivity and 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 that farmers are meant to make their own decisions of whether to participate and about the kind of activities to do in 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 program has attracted massive investment from the government and donors in the last 10 years.

Although evidence shows that NAADS program has had positive impacts on the availability and quality of advisory services provided to farmers, promoting adoption of new crop and livestock enterprises as well improving adoption and use of modern agricultural production technologies and practices (Benin *et al*, 2007), the growth and performance of the agriculture sector has been dismal and declining from 2.4% in FY 2009/10 to 0.3% in FY2011/12 (MFPED, 2009; 2012). This slow growth has contributed to unemployment, underemployment and poverty. For example, evidence show that farmer's yield for a majority of crops has 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 boost productivity and commercialization, the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) is pursing the Development Strategy and Investment Plan (DSIP) for the agriculture sector, covering the period 2010/11 to 2014/15. For example, the ongoing Agricultural Technology and Agribusiness Advisory Services (ATAAS) Project; which aims at technology generation, provision of agribusiness advisory services and creating the needed interface between agricultural research via the National Agricultural Research Organization (NARO) and agricultural advisory (extension) services via National Agricultural Advisory Services (NAADS) is one of sub programmes. Given the fact that interventions such as PMA and NAADS have not been very effective on impacting productivity (Benin *et al*. 2007), it would therefore be highly beneficial to evaluate effects of existing extension services on productivity of farmers.

The available empirical evidence from previous studies in Uganda provide mixed picture with regard to increased productivity of extension services(see e.g Hasan *et al*, 2013; Nkonya *et al*, 2009; Benin *et al*, 2010 & 2007; Betz, 2009 & 2011; Obwana, 2000; Muwonge, 2007). Generally, there is no consensus on the size of returns to extension investments. The equivocal results on return to extension have raised the level of skepticism among policy makers and development practitioners on the effectiveness of investments in agricultural extension. Evidence from empirical reviews and studies highlight concern over data quality and methodological issues regarding causality between extension inputs (see World Bank, 2011; Alston *et al*., 2000; Evenson, 2001; Anderson, 2007; Odhiambo & Nyangito, 2003; Betz, 2009; Anderson & Feder, 2004). The typical case fueling this concern was Bindlish and Evenson (1993) study in Kenya. The study found out 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. Gautam and Anderson (1999) using the same data after incorporating district fixed effects, the positive impact disappeared. In Uganda, Muwonge (2007) found that the significant positive impact of NAADs on yields disappears once endogeneity is controlled for. 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 program participation and the presence of unobservable characteristics.

Nevertheless, the majority of existing studies in and outside Uganda on the impact of agricultural extension on productivity and other outcomes assume that extension services come from only one source**:** extension workers. Therefore, a dummy variable of whether a farmer has been visited by 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 extension contact variable has an implied assumption that agricultural extension information is only obtained from extension workers. This implies that the available evidence on extension impact does not take into account the information exchange between farmers and other sources of agriculture information e.g radio, farmer-to- farmer, television, telephone, internet, newspapers, magazines/bulletins, and agriculture shows/exhibitions, among others. Thus the estimated coefficient on 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 this gap by controlling for knowledge spillovers occurring when farmers talk to each other and exchange information in model estimation.

1.1 Objective of the study

The main objective of this study was to investigate effects of agricultural extension services on farm yields in Uganda. More specifically, the study examined:
i) Examine the effects of extension contact on farm yields in Uganda.
(ii)Examine the relative effects of extension contact and other sources agricultural extension information on farm yields in Uganda.

1.2 Relevance of the study

Quantitative evidence supporting the ability of extension services to increase productivity is scarce. The lack of quantitative evidence is at least partly due to the fact that documenting quantitative changes and attributing them to extension is inherently difficult. The main objective of this study was to investigate whether agricultural extension services contribute to raising farm yields in Uganda. The study intended to address this questions putting into consideration the methodological challenges that have undermined the previous studies on linking agricultural extension and farm productivity particularly endogeneity and unobserved heterogeneity. Controlling for endogeneity for example, provide 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.

Firstly, by quantifying the accurate productivity effects of access to agricultural extension services, it can inform policymakers about the benefits of policy strategies aimed at assisting farmers to become more productive through extension services. Secondly, the analysis provides knowledge about the relative importance of the various farm inputs that determine farm productivity. Finally, the results provide insights on the potential benefits that may arise from different sources of extension provision on the performance of farms. This is useful from a policy point of view to obtain comparative results regarding the impact that various extension service providers may have in closing the technology and management gaps.

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 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 emphases from 1982 to 1997. In 1997 as per the Local Government (LG) Act of 1992, the provision of agricultural extension and other agricultural support services became the responsibility of local governments (Benin *et al*, 2011). The government of Uganda decentralised extension services in expectation that the services will be closer to the people, and more relevant. Consequently, the provision of agricultural extension and other agricultural support services became the responsibility of local governments in 1997, as per the Local Government (LG) Act (Benin *et al*, 2007). According to the provisions of the Local Government Act, 1997, local government have responsibility for liaison with the Central Government, district level policy issues, planning, coordination, monitoring and implementation of development programmes including those for agricultural extension. The decentralization process faced several challenges resulting to a number of market failures. For instance, extension provision operations were constrained by lack of funds to facilitate the work of extension agents at the local government level (Sserunkuuma and Pender, 2001).

Therefore, the rationale of recent reforms and reorganization of extension service provision arrangements was 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 ineffectiveness, irrelevancy and irresponsiveness of public extension and budgetary constraints (Mangheni and Mubangaizi, 2007). Thus, the publicly financed privately delivered extension system was adopted in 2001 to rectify past weaknesses related to rising concerns of efficiency of government-led extension such as the inability of the central government to handle the complexity of context-specificity required by extension services and the inability of the government to finance the requisite range of services as well as incorporate "best" practices in order to make extension delivery more efficient and effective (PMA, 2000).

NAADS was initiated in 2001 in six trailblazing districts (Arua, Kabale, Kibaale, Mukono, Soroti and Tororo), within which the NAADS program began working in 24 sub-counties. NAADS rolled out in 2002/03 into ten new districts (Bushenyi, Busia, Iganga, Kabarole, Kapchorwa, Kitgum, Lira, Luwero, Mbarara and Wakiso), in which it covered 46 sub-counties; it also expanded to 54 additional sub-counties in the trailblazing districts. In 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 in scale 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 end of the 2006/07 financial year, the NAADS program 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 farmers (representing about 20% of the national farming households) had reportedly received services of the program (NAADS, 2007; 2011). The program had contracted about 1,622 private-sector agencies to provide various specialized services on more than 40 enterprises, about 2,516 community-based facilitators (CBFs) had been trained to provide follow-up services and 40,000 farmer groups and 716,000 farmers (representing 20% of the national farming households) had received services from the program (see Benin *et al*, 2011).

The philosophical underpinning for the NAADS design is the need to empower farmers. It is grounded into 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 supply-driven to a demand-driven service. Other areas of NAADS intervention to support farmer productivity and participation in the market included support to formation of farmer groups and savings and credit cooperatives (Okoboi, 2011).

The operation of NAADs is done through a number of institutions defined under the NAADS Act of June 2001, involving farmer organizations; local governments; private sector; nongovernmental organizations (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 program coordinators at the district and sub-county levels and farmer groups to contract and supervise private professional firms to provide specialized advisory services according to farmers' priority enterprises and needs. In addition, community-based facilitators (CBFs) who are farmers are trained to provide quick follow-up advisory services according to farmers' needs (Benin *et al*, 2011).

Although the NAADS program is a public investment intervention, a great deal of the responsibility for bringing about the agriculture change rests on the shoulders of farmers who have to decide whether to participate in the program 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) that becomes the source of knowledge and skill development for farmers. It is only farmers that belong to a NAADS participating farmer group that can access the program 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. Sign posts indicating TDS are common things in many villages in Uganda. This is the channel through which the program is expected to generate its direct benefits. However, the TDSs, service providers, and CBFs are accessible as sources of knowledge to all farmers in the sub-county, irrespective of a farmer's membership status in a NAADS-participating farmer group. This is the channel through which the program is expected to generate indirect or spillover effects (Benin *et al*, 2011, NAADs, 2005). Considering this arrangement of extension provision and access in Uganda, the use of extension contact and the frequency of contacts make economic sense because the knowledge derived from extension services through extension contact impact farmers who may increase their production.

The current provision of agricultural extension services in Uganda under NAADs described above, reflect 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 & 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 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 has a number of benefits because its emphasis on adult learning principles and encouragement of farmer ownership of both problems and solutions (Marsh & Pannell, 2000; Woods *et al*, 1993).

The dominance of group-based approaches in agricultural extension in Uganda under NAADs program raises many issues. Despite the positive outcomes of NAADs such as high group membership and training received in several areas, use of improved technologies, marketed output, and wealth status of farmers receiving services from the program reported in a number program evaluations (Benin *et al*., 2007; ITAD, 2008; Nkonya *et al*., 2005; OPM, 2005; Scanagri, 2005). However, concerns about little productivity gains from the program is high. It is important to rigorously assess the impacts of the extension services and evaluate the productivity benefits of the extension service provision.

2.2 Empirical evidence

The strong relationship between high agricultural productivity and poverty reduction is wide (see Datt & Ravallion, 1998; Salami *et al*, 2010). For instance, agricultural productivity benefit farmers through increased production, creation of employment opportunities or indirectly, boosting their relative wages or reducing food prices. In developing countries, investments in extension services have the potential to improve agricultural and increase farmers' incomes (Anderson & Feder, 2004). It is this fact that enormous investment, funding and policy reforms have been directed into agricultural extension in many developing countries. Rausser (1992) classifies agricultural policies into groups: those that correct fro market failures. Lower transaction costs, or enhance productivity, and other policies that result from manipulation by special interest groups. 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 being 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 service 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'.

While there is considerable interest and efforts to understand the issues related to agricultural extension in developing countries and the literature is growing, rigorous impact evaluations of agricultural extension interventions are less common (Anderson & Feder, 2004). The impact evaluation face 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, farmers' characteristics, and so on. Furthermore, 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; Owen *et al*, 2001; Anderson & Feder, 2004; Cerdán-Infantes *et al*, 2008; Betz, 2009).

The empirical literature on the productivity effects of agriculture extension services from a number of studies is not conclusive. For instance, Betz (2009) has noted that previous studies on productivity effects of agricultural extension have varying results. The mixed results regarding the impact of agricultural extension on productivity is as a result of how the methodological issues of endogeneity, heterogeneity and measurement of productivity variable are addressed. Productivity - agriculture extension literature reveals a number of methodological challenges that make it difficult to make broad generalizations about the productivity effects of agricultural extension services (Odhiambo & Nyangito, 2003; Betz, 2009; Anderson & Feder, 2004; World Bank, 2011). For example, the available empirical research on the effect of agricultural extension services, show large positive rates of return to 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 endogeneity of program participation and the presence of unobservable characteristics that might determine participation and be correlated with the outcome variable (see e.g Betz, 2009, Cerdán-Infantes *et al*, 2008, Dercon *et al*, 2008, Owen *et al*, 2001).

Nevertheless, Evenson & Mwabu, (1998) argued that previous studies on extension effects of farm yields have ignored an important policy issue 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 endogeneity problem. However, using either meta production function or the total productivity index, previous studies that have addressed the relationship between agricultural productivity and extension services have mainly used the traditional ordinary least squares (OLS), instrumental variable (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 that the use 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, Heckamn 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 IV approach however, has practical difficulty to identify 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 on 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 double-difference (DD) combined with other methods to deal with the initial conditions that affect the trajectory of impacts. Typically, the PSM is used to select program participants and nonparticipants who are as similar as possible in terms of observable characteristics that are expected to affect participation in the program 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 program 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. The 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 & Mwabu (1998) used the quantile regression technique and the results reveal that extension services have a discernible impact on productivity and that the impact was at the highest top 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 & Nyangito, 2003).

Notwithstanding the above, although the development of statistical methods to better understand and accommodate potential biases has been a major methodological achievement of modern quantitative microeconomics analysis; few studies have effectively addressed the issues of selection and heterogeneous treatment effects concerns (Xie et al, 2011). In as far as treatment effects literature, despite of 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 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 effect. The ivtreatreg command provides consistent estimates Average Treatment Effect (ATE), the Average Treatment Effect on Treated (ATET) and the Average Treatment Effect on Non-Treated (ATENT), as well as the 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 of: (1) The Average Treatment Effect (ATE); (2) The Average Treatment Effect on the Treated (ATET); and (3) The Average Treatment Effect on the Non-Treated (ATENT) (Myers et al, 2012) need to be defined and estimated.

In any empirical studies involving the estimation of crop yields, the main key concerns are related to how 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. This is involves 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 easy to solve when it comes to estimating the household farm crop yields. Indeed, numerous studies show that crop cuts gave 14 to 38 percent higher yield estimates than whole plot reference harvests, while farmer recall estimates overestimated yields by less than 15 percent (Fermont and Benson, 2011). However, notwithstanding the challenges associated with farmer estimation method, empirical evidence is accumulating that estimates by farmers do not necessarily result in a larger total error than that obtained using the crop-cut method. (Fermont and Benson, 2011; Diskin, 1999). Nonetheless, in many developing country agricultural systems because of mixed cropping (or intercropping), it has proved to a challenge for measuring and interpreting data on key specific crop yields because it may not be possible 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.

In Uganda, because farmers want to spread risks, diversify their production, and increase total output of individual fields, intercropping is practice predominantly done by over 70 percent of farmers in Uganda (Fermont and Benson, 2011). Therefore, in such situations measuring yields for specific primary crops could be seriously underestimated. Whereas a number of approaches such dividing the crop areas by the number of crops grown on them or dividing total production of crop x by the whole area planted to both crops have been adopted to address the intercropping effects, 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 aces. In most cases, crops do not share the land equally, seriously impairing the validity of the first approach. However, the availability of price data that allows the computation productivity indicator from weight yield to value yield is one of the appropriate answers to problem of intercropping. In this current study, since using actual yield measures per crop when intercropping is practiced and would be misleading because individual crop yields will be artificially low (Peterman et al, 2010), crop productivity model estimations was estimated at aggregated crop level.

3.0 Methodology

3.1 Analytical framework

The analytical framework to use is developed within the conventional potential (latent) outcome framework (see Heckman and Robb, 1986; Chernozhukov and Hansen, 2005). Potential real-valued outcomes that vary among individuals or observational units are indexed against potential treatment states and denoted Yd. 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 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:

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

where y_{1i} is the crop yield for farmer i who had contact with extension workers[3], and y_{0i} is the crop yield for farmer *i* who had no contact with extension worker. Therefore, identifying TE*i* 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 behavior 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 recover reliably the causal effect (Rubin, 1977).

Assuming that d is the treatment binary variable (1=had extension contact) and that an independent, identically distributed sample of the population, this rules out that a treatment effect on farmer *i* affects a farmer *j*. Indeed, this assumption is not very restrictive since only few farmers get access to extension workers 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 & Rubin (1983), the first way to estimate treatment is to compute the average treatment effect (ATE)[4].

We have the following equations:

$$y = y_1 d + y_0 (1 - d)$$

$$y = x\beta + \alpha d + \varepsilon \quad \ldots\ldots (2)$$

However, the selection into extension program is not observed and therefore treatment is endogenously defined because of selection bias. In econometrical terms, this implies the residuals of the models are not independent of the treatment. For instance, if farmers (productive farmers) with highest unobserved preference for extension services choose to participate in agricultural extension program more than the farmers with 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) has 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 rather work with more experienced farmers (see also Owen *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 extension contact variable is endogenous since most of the extension contacts are farmer initiated.

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[3] We focused on household farmers who do crop production as the main activity. This is because 80% of sample population is crop farmers, with livestock contributing 2.36%.

[4] In this study, the ATE reveals how the mean outcome would differ if all eligible farming households who had extension contact versus the mean outcome if all eligible farming households had no extension contact.

Nonetheless, extension staffs select farmers based on some characteristics such as performance and size such that some farmers are visited more frequently than others (Birkhaeuser *et al*, 1991). The remedy to this problem has been mainly solved by Instrumental Variables (IV) approach. However, the application of IV requires the availability of at least one variable *z*, called "instrumental variable", 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 & 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.

Although numerous studies on agricultural extension have used instrumental variables, finding a variable correlated with the participation in extension programs but not with the studied outcome is not an easy task since by program 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 a loan, total farm debt, and the previous visit of an extension agent (not of the program). In this study, membership to farmer group and distance in kilometers to extension services were used as instruments. These instruments have satisfied the relevance and exogeneity conditions. Like other studies, farmer group membership and distance to extension services are significantly associated with probability of participating in the agricultural extension programs but with no significant relationship with out per acre (Hasan *et al*, 2013; Bindlish *et al*, 1993; Muwonge 2007; Benin *et al*, 2007; Betz, 2011).

Extension agents are some of the most important sources of agricultural information in any country. The extension services include transferring knowledge to farmers, advising and educating farmers in their decision making, enabling farmers to clarify their own goals and possibilities, and stimulating desirable agricultural developments. Farmer's exposure to such information as result of extension contact reduces subjective uncertainty and therefore increases the likelihood of 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, Lau, and Slade (1987) have argued that showed training of farmers pays and that farmer education can help even without new technologies. Therefore, impact of agricultural extension services on productive efficiency can be evaluated through its marginal product, where extension is considered as a factor of production or as a factor explaining individual technical efficiency measures (see Kaliba & Engle, 2004).

This implies that the impact of extension services on farm productivity can be measured through output gain due to elimination of technical inefficiency. Thus, if we assume agricultural extension contact as 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 focused only on the worker effect of extension contact. The worker effect of schooling refers to the increase in farm output that accrues directly 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 & Shand (1985) argued that an illiterate farmer, without formal training, can understand a 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 the larger the number of extension visits per farming household, the greater the intensity and effectiveness of the agricultural extension service delivered to farmers. Thus the frequency of extension visits is expected to be associated with higher output, *ceteris paribus*. The following productivity equation was specified for a given household i[5] :

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

where *Yield* is the value of agricultural output per acre for household i. *D* is a variable that capture agricultural extension contact (frequency of visits by extension agent). The frequency of visits by extension is used because it captures the intensity of extension effort (Dercon *et al*. (2009)[6]. The use of a continuous variable, such as the number of extension visits, provides a more accurate description of the intensity of extension effort (see Birkhaeuser *et al.* 1991).

X is vector of exogenous variables that relate to agricultural inputs (capital, labour and technology). The variables include age of household head, adult labor force supply (both family and hired labour), household head schooling, land size, number of crop plots and distance to local markets. Dummies for gender of the household head, access to irrigation system, use of fertilizers and access to credit were included in equation.

3.2 Functional form of production function

In estimating production functions, two models are commonly used: the Cobb-Douglas model and the transcendental logarithmic (translog model). However, the Cobb-Douglas although popular, has been questioned because of its restrictive assumptions such as homogeneity, separability and elasticity for substitution (Lyu *et al*, 1984). Compared with 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. The aim of this study was to adopt the translog form of production function and tobit model. However, translog production estimations violated the monotonocity requirement. The monotonocity requirement is fulfilled if there are positive marginal

[5] The i^{th} subscript is dropped henceforth

[6] Betz (2009) found that the number of extension visits a household receives has a significant positive effect on the value of output of the smallest and largest farms.

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 monotonocity requirement was not fulfilled. We adopted log-linear model specification over linear specification with the help of the Box-cox test[7]. The tobit model was abandoned because the productivity indicator (yield per acre) was observed for all households, hence it was not truncated at zero.

3.3 Estimation strategy

The estimation strategy was first to estimate the effects of an endogenous binary variable (extension contact) on productivity of farmers using ivtreatreg STATA command. The treatment effects model estimates the effect of the endogenous binary treatment, D_i on a continuous, full observed outcome variable Y_i, conditioned on the independent variables Xi and Z_i. We adopted the Probit-2sls (IV regression estimated by Probit and Two Stage Least Squares (2SLS) over other models estimated by ivtreatreg commnad[8]: Cf-ols (Control-function regression estimated by OLS), Direct-2sls (IV regression estimated by direct two-stage least squares), Probit-ols (IV two-step regression estimated by Probit and ordinary least squares), and Heckit (Heckman two-step selection model) because it is more *efficient* than Direct-2SLS (Cerulli, 2011). In probit-2SLS, the probit of the endogenous *binary* variable (D) is estimated on X and Z, and obtain the “predicted probability of *D*”. In the second step, 2SLS is applied with the generated predicted probabilities of D used as instrument for *D*.

The model was estimated assuming heterogeneous response to treatment by controlling for observable confounding factors (farmer’s access to credit, market, and irrigation, gender, education, experience , use of fertilizers, land size, locational dummies and labour supply). The treatment analysis aimed at estimating whether agrcultura households who had extension contact are better than those farmers who had no extension contact in terms of productivity. The estimation calculates the Average Treatment Effect (ATE), the Average Treatment Effect on Treated (ATET) and the Average Treatment Effect on Non-Treated (ATENT), as well as the estimates of these parameters conditional on the observable factors **x** (i.e., ATE(**x**), ATET(**x**) and ATENT(**x**)).

To estimate the worker effect of extension contact on crop productivity while controlling for other production inputs and spillover effects of information exchange between farmers, a log-linear model specification was estimated[9]:

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[7] Box Cox = N/2*log $(RSS_{largest}/RSS_{smallest}) \sim \chi^2$. If estimated value exceeds critical value (from tables Chi-squared at 5% level with 1 degree of freedom is 3.84) *reject* the null hypothesis that the models are the same (ie there is a significantly different in terms of goodness of fit).

[8] This procedure *does not* require for consistency that the process generating D is correctly specified

[9] According Maddala (1988), the semi log model is considered appropriate for multiplicative relationship.

$$\ln[Yield] = \beta_0 + \beta_1 EXT\_visits + \beta_2 NP + \beta_3 NP\_sq + \beta_4 Exp + \beta_5 Exp\_sq + \beta_6 Yrs\_sch + \beta_7 Land + \beta_8 Land\_sq + \beta_9 F\_labour + \beta_{10} H\_labour + \beta_{11} D\_Mkt + \beta_{12} HCI + \beta_{13} D1 + \beta_{14} D2 + \beta_{15} D3 + \beta_{16} D4 + \varepsilon$$

Where;

$\beta_0 - \beta_{16}$ 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 below:

Table 1: Variable description

Variable	Description
In $[Yield]$	Logarithm of yield per acre for household i
EXT	Number of extension visits received by the farmer in past 12 months
NP	Number of plots owned by the household
NP_sq	Number of plots owned by the household squared
Exp	Managerial experience of farming household head in complete years
Exp_sq	Managerial experience of farming household head in complete years squared
Yrs_sch	Years of schooling of the household head
Land	Total household cultivated land in acres
Land_sq	Total household cultivated land in acres squared
F_labour	Family labour (number of persons)
H_labour	Hired labour (number of persons)
D_market	Distance from local market in kilometers
D1	Dummy for credit access (1 if yes, 0 otherwise)
D2	Dummy for fertilizer use (1 if yes, 0 otherwise)
D3	Dummy for access to irrigation (1 if yes, 0 otherwise)
D4	Dummy for gender of household head (1=male, 0=female)

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 extension contact is endogenous and thus adopted an instrumental variable estimation to tackle endogeneity problem. Specifically we employed the most efficient variant of IV estimators, the two-stage least squares (2SLS) framework where we regressed the endogenous variable on a vector of instruments and exogenous variables as described above. The instruments used were membership to farmer group (dummy, 0/1) and distance to extension services (kms). To test for endogeneity of inputs, Wu-Hausman F test was used, the null hypothesis being that the inputs are exogenous. To assess the relevance of instrument, the Kleibergen-Paap rank Wald statistics was used. Hansen-Sargan test was employed to test for over-identification with joint null hypothesis being that the instruments are valid. To test for exogeneity condition, Bound *et al.* (1995) recommendation of conducting an *F*-test of the effect of the instrument on the outcome variable residuals was conducted. It involves regressing the outcome variable residuals from the IV estimates against the instrument in order to ensure that the instruments are not directly correlated with outcome variable.

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 unobserved ability of the farm decision maker. Although, such variables are not available in UCA data, numerous empirical studies have proved that the bias arising from omission of unobserved ability and motivation is not large (Weir, 1999). Thus, endogeneity issue associated with years of schooling was not controlled for in this study.

Another source of bias is related to selectivity that may arise due mode of extension contact. To address the biases that may arise from selectivity due to extension contacts either on demand or routine, dummies for whether household had extension contact through routine and demand only were put separately in equation (3). The dummies captures whether the effects of extension contact on productivity differ by mode of extension contact.[10]. The extension contact through demand means that the farmer called the extension staff for advise whereas "routine" is where the extension staff made pre-determined trips in the area to advise the farmers.

The other potential bias is related to farmer's responses to agricultural extension that may arise if farmer is practicing crop farming or food production (level of commercialization). To account for this variability in responses to agricultural extension due whether a farmer is producing for market or domestic consumption, widely acceptable measurement index of the level of agricultural commercialization at household level was used to generate dummy that classified households into commercialized farmers and non commercialized (0/1). The Household Commercialization Index (HCI) was defined as the ratio of the gross value of all crop sales per household in given time to the gross value of all crop production. Household who sold less than 50 percent of their produce were classified as non-commercialized and those above commercialized. This dummy was plugged in the equation (3) to allow the effect of extension contact to be different for whether a farmer is commercialized or not.

In estimating extension effects on productivity, another possible source of bias may come from existence of information spillovers between farmers. To capture relative impact of extension contact while controlling for other sources of agricultural information, equation (3) was estimated incorporating a dummy variable for farmer to farmer information exchange. According to Betz (2009), the use a farm-level extension contact variable should be accompanied by a control for knowledge spillovers occurring when farmers talk to each other and exchange information to avoid biasing the results upwards. For instance, there are farmers who may have been visited by an extension agent, but obtain the same

[10] The census had question "How many times (on demand and by routine) did the agricultural household members received advice on issues (type of seed to use; plant protection; use of organic and inorganic fertilizers; when to plant, crop spacing, weeding, thinning etc; use of animal seeds; use of veterinary drugs, insemination; and market information) during the last 12 months?"

potentially output increasing information from a neighbors, and need to be catered for in the statistical estimation.

Regional dummies were also included in equation (3) capture heterogeneous effects due to locational and agro-ecological related characteristics of the study households. The regional dummies represent Central, Eastern, Western, and Northern parts of the country. To address the heteroskedasticity that may be present, Huber-White sandwich estimator was used in the regression estimations.

3.4 Data and source

The data to use in this study comes from the 2008/2009 Uganda Census of Agriculture (UCA). The census was administered by the Ugandan Bureau of Statistics (UBOS) and covered all the 80 districts in the country as of 1st July 2007. Small and Medium scale holdings constituted the sampling frame from which a sample was drawn. Since, the contribution of production (crop and livestock) by the Private Large-Scale and Institutional Farms (PLS & IFs) has been increasing over time, the census also covered PLS & IFs on a complete enumeration basis. The UCA 2008/09 collected data on various structural characteristics of the agricultural holdings such as: Number and Size of holdings, Land tenure system, Demographic characteristics of the holder and his/her household, Use of agricultural labour; and Use of implements and farm machinery, access to agricultural extension services and source, technological adoption, market access etc. Data was also collected on: Crop area and crop production; livestock numbers and aquaculture. A stratified two-stage sample design was used for the small and medium-scale household-based agricultural holdings. At the first stage, Enumeration Areas (EAs) were selected with Probability Proportional to Size (PPS), and at the second stage, households which were the ultimate sampling units were selected using systematic sampling (UBOS, 2010).

Table 2 summarizes the characteristics of the study households, contrasting between farmers with and without access to agriculture extension services. The summary statistics show a significantly higher farm yield per acreage among farmers who had extension contact. The number of plots, cultivated land size, years of schooling, labour supply (family and hired), and level of commercialization are significantly larger for farmers who had access to extension services. Nonetheless, the summary statistics show a significantly larger proportion of households who had extension contact were male headed, fertilizer and credit users, and members of farmer groups. However, in terms of managerial experience, the results show that farming households who had no extension contact were significantly more experienced.

Table 2: Household level summary statistics

Variable	All households (N=30,720)		Had no extension contact (N=24,310)		Had extension contact (N=6.410)		t-statistic
	Mean	SD	Mean	SD	Mean	SD	
Yield per acre in metric tones	1.92	24.23	1.73	10.98	2.61	48.54	-2.59*
Number of plots	10.32	14.50	10.10	14.35	11.15	15.05	-5.14*
Years of schooling	18.56	13.94	17.94	14.01	20.93	13.41	-15.32*
Managerial experience	21.36	23.27	22.00	23.73	18.91	21.23	9.49*
Size of household cultivated land in acres	2.54	3.36	2.43	3.31	2.96	3.50	-11.30*
Adult family labour	1.90	0.99	1.88	0.98	2.01	1.02	-9.99*
Adult Hired labour	6.70	29.11	5.69	25.54	10.50	39.62	-11.78*
Distance to local market (KM)	5.38	14.41	5.38	14.06	5.38	15.68	-0.01
Male head of household dummy	0.80	0.40	0.79	0.41	0.82	0.38	-6.64*
Household commercialized index	0.23	0.27	0.22	0.27	0.25	0.27	-9.06*
Dummy for fertilizer use	0.31	0.46	0.28	0.45	0.41	0.49	-19.60*
Central region	0.19	0.39	0.20	0.40	0.16	0.37	5.67*
Eastern region	0.34	0.47	0.34	0.47	0.34	0.47	-0.60
Northern region	0.18	0.39	0.17	0.38	0.21	0.41	-6.13*
Western region	0.29	0.45	0.29	0.45	0.29	0.45	0.93
Dummy for credit access	0.12	0.33	0.10	0.30	0.22	0.42	-27.69*
Dummy for irrigation use	0.01	0.11	0.01	0.10	0.02	0.14	-6.71*
Dummy for membership to farmer group	0.15	0.36	0.09	0.29	0.40	0.49	-65.24*

*Note: * Indicate significance level at 5%.*

4.0 Descriptive and empirical findings and discussion

4.1 Descriptive findings

Table 3 summarizes the characteristics of the study households in relation to access to agricultural extension services and information. The summary statistics show that 21 percent of agricultural households had been visited by an extension worker during the past 12 months. However, of these households, the larger proportion of households had extension contact through both routine and demand form of extension provision (10%). The proportion of household who initiated extension contact was 3% compared to 8% who received extension contact through routine visits by extension agents. The results further shows that farmers receive agricultural information from a multitude of sources, such as mass media, extension agencies, fellow farmers, agricultural shows, etc. The majority farming households use radio as the main source of agricultural information (88%) followed by farmer to farmer at 72 percent. Surprising however, the much funded public extension system (NAADS) and extension workers in general was the source of agricultural information for 19 per cent and 11 percent of farming households respectively. Newspaper and agricultural shows /exhibitions are becoming significant sources of agriculture information for many households in Uganda, used by 3.2% and 4.5% of sampled farming households.

The fact that the majority of farming households rely on radio and farmer to farmer for agriculture information; implies that in order to increase access to extension under the current agricultural extension provision, new modes of reaching out to farmers that reflect the local information needs of farmers could have significant impact on access improvement. Therefore, there is need to promote agriculture information access through other channels other than usual demand and routine extension service provision. In Ethiopia for example, Farm Radio International (FRI) initiative was started in 2011 to promote the use of ICT for agriculture. The initiative supports local radio broadcasters with necessary skills to develop content that responds to the needs of local small-scale farmers. Such initiatives are lacking in Uganda, yet they would take advantages of many local radio stations located in various districts of the country to reach many unreached farmers in the rural areas.

Nevertheless, it is evident that farmer to farmer information exchange is a significant source of agriculture information yet no efforts has been done to make use of it. In health promotion and prevention in Uganda, there is robust evidence that use of Community Health Workers/Village Health Workers has made a valuable contribution to community development and, more specifically, improving access to and coverage of child and maternal health services. We argued that the fact that many farmers have relied on their fellow farmers for various agriculture information needs; government and other stakeholders need to think about promoting community engagement in scaling up extension service uptake borrowing from the health sector. We believe the recruitment and training of village extension workers (village farmers) per village represent an important resource potential in providing and complementing the public extension services to underserved farming populations and that should be exploited as it has happened in the health sector in Uganda.

Table 3: Access to agricultural extension services and information

	Number of households (N= 30,720)	Mean	Standard deviation
Access to agricultural extension			
Access to agricultural extension services (yes=1; otherwise=0)	6,410	0.21	0.41
Access to agricultural extension services on demand (yes=1; otherwise=0)	877	0.03	0.17
Access to agricultural extension services on routine (yes=1; otherwise=0)	2,545	0.08	0.27
Access to agricultural extension services on both demand and routine (yes=1; otherwise=0)	2,988	0.10	0.30
Sources of agricultural information			
Radio	26,914	0.876	0.329
Television	497	0.016	0.126
Telephone	480	0.016	0.124
Internet	69	0.002	0.047
Newspapers	980	0.032	0.176
Magazines/Bulletins	281	0.009	0.095
Extension workers	3,400	0.111	0.314
Farmer to farmer	22,207	0.723	0.448
NAADS	5,919	0.193	0.394
Agric. Shows/Exhibitions	1,373	0.045	0.207
Others	2058	0.067	0.250

4.2 Empirical findings

4.2.1 Treatment effects of participation in extension programs

The following results summarize the results of treatment effect model which has been applied to estimate the productivity effects of agricultural extension contact/access. The first results presented in table 4 below assume no selection into homogeneous treatment and are based on an Ordinary Least Squares (OLS) specification of household crop yields. The results show a significant effect of extension contact on yield controlling for various household characteristics. This implies that ceteris paribus, household who had extension contact are more productive than farming households with no extension contact by more than 1 metric tonnes of output. The positive and statistically significant effect of extension access underscores the important role played by agricultural extension services in increasing production and productivity in farming systems in the country. However, because of selection into homogeneous and heterogeneous treatment, we adopted *ivtreatreg* stata command that estimates treatment effects model using probit-2sls[11]. The underlying assumption of the model estimation is that ATE is no longer a singleton when there is heterogeneity and selection in treatment outcomes and thus reports the ATE, ATET and ATENT conditioning on household characteristics. We checked whether ATE ≠ ATE (Xi), ATET ≠ ATET (Xi) and ATENT ≠ ATENT (Xi) and the results confirmed that there are not equal. This implied that there was selection into treatment and treatment effects are heterogeneous, hence the need to control for heterogeneous treatment response in the estimation.

Table 4: OLS estimate of Average treatment effects (ATE)

Yield	Coef.	Std. Err.	t-value	P-value
Access to extension services	1.140	0.348	3.280	0.001
No_plots	-0.032	0.015	-2.130	0.033
No_plots_sq	0.000	0.000	1.660	0.097
Years of schooling	0.009	0.014	0.620	0.533
Experience	0.012	0.009	1.330	0.184
Cultivated_land	-0.551	0.078	-7.070	0.000
Cultivated_land_sq	0.013	0.002	5.140	0.000
Family_labour	0.093	0.145	0.640	0.522
Hired_labour1	0.006	0.005	1.310	0.191
Distance market	0.001	0.010	0.090	0.928
Credit access	-0.625	0.433	-1.440	0.148
Access_irrigation	14.383	1.261	11.410	0.000
HHgender_male	0.549	0.368	1.490	0.136
Fertilizer_use	-0.576	0.311	-1.850	0.064
Eastern	-0.867	0.401	-2.160	0.030
Northern	-1.205	0.469	-2.570	0.010
Western	0.014	0.414	0.030	0.973
Constant	2.661	0.648	4.110	0.000
Number of obs	30720			
F(17, 30703)	13.94			
Prob > F	0.000			
R-squared	0.0077			

The results of the ivtreatreg command are presented in the appendix 1. Step 1 probit results show that membership to farmer group is partially fairly correlated with extension contact, thus it can be reliably used as instrument for participation in extension programs. For example, membership to farmer group increases the probability of participating in extension program with more than 100 percentage change. The results also show that education, managerial experience, cultivated land, labour supply, credit access, access to irrigation and fertilizer use have significant influence on farmer's participation in agricultural extension programs.

[11] 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

Step 2 instrumental variable results shows that the ATE (the coefficient of extension contact) is no more significant and negative. According to Cerulli (2011 & 2012), the ATE obtained by instrumental variable methods is always not significant. The negative sign means that farming households who had extension contact would have been less productive if they had not got access to extension services. We used a bootstrap procedure with 100 replications to estimate standard errors for testing ATET and ATENT significance. The results reported in appendix 2, shows both ATET and ATENT are not significant and the values are quite different but not too much far from that of ATE[12]. The summary statistics of the ATE(x), ATET (x) and ATENT(x) presented in table5 reveal that both ATET (x) and ATENT(**x**) have negative mean values. The negative mean of ATET (x) implies that farming households who had extension contact would on average produce less than one tons per acreage if they get more access to extension services. This may be referred to as diminishing returns of extension contact; such that increasing extension contact to a farmer who already had contact may results into fewer yields per extension visit. Similar studies have revealed that more extension beyond a given threshold may not significantly results into higher productivity effects (Betz, 2009; Owen *et al*, 2001). The mean value of the ATENT(**x**) around -0.74 predict that on average farming households who had no extension contact would have been more productive if they had extension access. This underscores the marginal benefits of increasing farmer's access to extension and advisory services to unreached farmers. Therefore, government efforts should be focused on scaling up extension access among farming households and more importantly on the quality of information provided to farmers at any opportune time.

Table 5: Summary statistics of ATE(x), ATET(x) and ATENT(x) in model probit-2SLS

Statistics	ATE_x	ATET_x	ATENT_x
Maximum	40.01	34.14	40.01
Minimum	-87.84	-86.38	-87.84
Mean	-0.72	-0.68	-0.73
Standard deviation	9.34	11.85	8.56

4.5 The impact of extension contact on aggregate crop productivity

In estimating the impact of extension contact on aggregate crop productivity, the modified translog production was found to be inappropriate and a choice had to be made either to use the linear or log linear model Cobb-Douglas production specification. The appropriate functional form was formally tested using the Box-Cox test. The results of the test proved that log linear specification performs better than the linear specification. Therefore, log linear model in which the dependent variable is measured in logs and the independent variables in levels was used to ascertain the impact of extension contact on crop productivity

[12] A simple check of ATE = ATET $P(D=1)$ + ATENT $P(D=0)$ confirms the expected result.

while controlling for other variables. To control for endogeneity associated with extension contact in productivity log linear model, instrumental variable estimation was used. We perform several diagnostic tests to determine the endogeniety of extension contact variable, relevance and exogeneity of instruments and over identification. We performed a Wu-Hausman test to determine if the coefficients of the OLS model are significantly different from those produced by the IV estimator. We find no significant difference exists between the two coefficients, implying it is not necessary to correct for endogeneity of extension contact (p = 0.1757). The Hansen-Sargan overidentification test is passed in the model indicating that the joint null hypothesis on validity of instruments is not refused (p-value=0.2765) and instrumental variables are independent of structural error term and confirm that instruments are valid.
We performed several statistics to judge the explanatory power of the instruments. We see that they are jointly significantly different from zero, with a p=value of 0.0000. The adjusted R-squared is 0.233 and their partial R squared is 0.037. The F statistic is 213suggest instruments are sufficiently strong. According to Stock and Watson (2003), a minimum F-statistics of 10 is sufficient for validity.

Table 6 provides OLS and 2SLS results of the productivity effect of extension contact. We also present estimations of the same equations without incorporating the dummies for extension contact through routine and demand, and level of commercialization (appendix 3). Comparing the results in table 6 and appendix 3, it is evident that the exclusion of these dummies in productivity model tends to increase the effect of extension upon productivity, justifying their use in model estimations. The extension contact IV estimate is found to be larger than the OLS estimate. This implies that estimating the productivity effects of extension contacts using the OLS underestimate the impact of extension contact on productivity. The OLS extension contact coefficient is positive and significant at 5 percent implying that on average extension contact increase productivity of the farmers by 1.1 percent other factors kept constant. This is agreement with many studies in Africa that show positive impact of extension contact (Owen *et al*, 2001; Ragasa *et al*, 2012). Recent evidence from Uganda shows that government extension services on average improve crop productivity by 3.42 percent (Hasan *et al*, 2013).

For the IV estimates, although suggestive of an association between extension visits and productivity, the results did not achieve statistical significance at 5 percent (p-value = 0.07). However, at 10 percent, it is statistically significant implying that access to agriculture extension services has favourable effects on farm productivity since extension contact (visits) is just a basic tenet of the overall agricultural extension. Recent evidence from Ethiopia show that it is the quality of extension services that matters for farmer productivity rather than the frequency of extension visits (Ragasa *et al*, 2012). Owen *et al*, (2001) after disaggregating extension visits into 1 or 2 visits and 3 or more visits, found out that a frequency of three or more than three per year had no clear effects on productivity.

The insignificant productivity effect of extension contact variable in 2SLS at 5 percent may perhaps be explained by the following reasons. Firstly, the number of extension visits variable may be underestimated. This may be true because some farmers may not be in position to recall the number of extension visit received over the span of 12 months, given the number of extension service providers in Uganda. Farmers in Uganda receive extension services from government providers (NAADs) and other private providers (farmer associations and NGOs). Therefore, if extension contact truly has an effect, but a substantial number of households fail to report the number of extension contacts accurately, then our estimated effect may be biased. Secondly, 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.

In addition, much of the extension service efforts in Uganda, including the NAADs services provision, focus on input delivery and persuading farmers to adopt new technologies, crop varieties, marketing 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 NAADs program did not have any statistically significant effect on 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 program had never been implemented (Benin *et al*, 2011).

Nonetheless, it is evident in both OLS and 2SLS results that access to extension contact on demand has more significant impact on productivity. For example, the coefficient on extension contact dummy on demand in OLS results represents a higher significant effect on productivity (at 25 percent compared to 11 percent for extension contact on routine). In 2SLS estimation, the productivity role of extension contact on routine disappears while that of demand is still positive and significant at 18 percent. This result show that farmers who initiate extension contact from extension providers are more likely to be productive than those who receive extension contact through routine visits by extension agents. This findings implies that to enhance extension productivity effects among farmers in demand driven extension delivery system, efforts should focus on empowering farmers to demand extension services other than extension staff making pre-determined trips to advise the farmers.

Table 6: OLS and IV Estimates of Aggregate Crop productivity Model

In_Yield	OLS		2SLS	
	Coef.	p-value	Coef.	p-value
Number of extension visits	0.011	0.004	0.040	0.066
No_plots	0.000	0.882	0.000	0.903
No_plots_sq	0.000	0.098	0.000	0.077
Years of schooling	0.005	0.000	0.005	0.000
Experience	0.001	0.118	0.001	0.154
Cultivated_land	-0.260	0.000	-0.261	0.000
Cultivated_land_sq	0.004	0.000	0.004	0.000
Family_labour	0.067	0.000	0.066	0.000
Hired_labour1	0.001	0.010	0.001	0.019
Distance to market	-0.002	0.000	-0.002	0.000
HHgender_male	0.071	0.001	0.073	0.001
Fertilizer_use	0.130	0.000	0.120	0.000
Credit_access	0.074	0.003	0.058	0.037
Access_ irrigation	0.308	0.000	0.298	0.000
Farmer_farmer	-0.026	0.178	-0.019	0.353
Eastern region	-0.206	0.000	-0.208	0.000
Northern region	-0.765	0.000	-0.770	0.000
Western region	0.612	0.000	0.611	0.000
Commercialised_dummy	0.247	0.000	0.244	0.000
Extension_routine_dummy	0.112	0.000	0.028	0.696
Extension_demand_dummy	0.248	0.000	0.176	0.017
Constant	-0.652	0.000	-0.650	0.000
Number of obs	30720	-	Number of ob	30720
F(21, 30698)	435.12	-	Wald chi2(21)	9134.97
Prob > F	0.000	-	Prob > chi2	0.000
R-squared	0.2509	-	R-squared	0.2497

There are several other variables that were significant in explaining aggregate crop productivity. The year of schooling had significant positive effect on crop productivity implying that an additional year of schooling is associated with increasing crop productivity. This result was expected since more educated are expected to be associated with higher output, *ceteris paribus*. The positive and statistically significant effect of schooling provides an economic rationale for policy interventions to increase access to education in the country. This finding concurs with numerous studies that have found a significant positive of schooling on production particularly in areas where farmers are modernizing (Weir, 1999). Nevertheless, in Uganda, Appleton and Balihuta (1996) found a negative effect of an additional year of schooling. They argued that it is possible that the attitudes imparted in school, particularly at higher levels, undermine technical efficiency of farmers who view farming as secondary activity and inferior to urban wage employment. Weir (1999) also argued that exposure to education can reduce farm productivity by creating negative attitudes toward farm labour or by reducing time spent in 'on the job training,' leading to a negative coefficient.

Managerial experience of the household head although positive, had insignificant effect on crop productivity. Cultivated land size is inversely related to productivity. The result is statistically significant implying that higher cultivated land sizes is associated with low output per acre by 26 percent. Similar conclusions have been reached at 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 also numerous studies elsewhere that have confirm 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 cultivated land has positive significant effect on productivity, indicating a U-shape relationship between agricultural crop productivity and cultivated land size. That is, agricultural crop productivity first decreases with cultivated land size, then increases after a threshold. Nevertheless, the number of plots per farm households usually used as measure of land fragmentation is not statistically significant. This implies that land fragmentation has no effect on crop productivity.

The coefficients on family labor and hired labor are both positive and highly significant as expected. However, the contribution of family labour is more than that of hired labour. For example, percentage change in productivity following a unit increase in family labour is 7 percent compared to 0.1 percent for hired labour. This result is expected because in Uganda family labour contribute greater share of overall production and has greater incentive to work harder than hired labor (Betz, 2011).

The significant coefficient on household gender implies that other factors being constant, male headed households are more productive than female headed households. Access to credit exhibited a positive significant relationship with crop productivity. This implies that when household receive credit they invest in productivity enhancing activities. Similar studies in Uganda have demonstrated that access to credit significantly improve the productivity of farmers (Obwana, 2000). Use of to fertilizers and water irrigation has been proven as important drivers of agricultural productivity among farmers in Sub Saharan Africa. Indeed the results from the study shows that households who had access to irrigation and use fertilizers are more productive than those who had no access to irrigation and fertilizers by about 30 percent and 13 percent respectively.

Farmer to farmer information exchange dummy accounting for knowledge spillovers occurring when farmers talk to each other and exchange information is not statistically significant. However, distance to the market has a significant and negatively related with farmer productivity. The percentage decline in productivity following a unit increase in distance to market is 0.2 percent. The commercialized dummy that captures the variability in the responses to agriculture extension related to whether a farmer is commercialized or not is statistically significant and positive. This implies that farmer's who market oriented are more productive than their counterparts by more than 24 percent.

All regional dummies included in the model are statistically significant. However, except for western region, the coefficient of eastern and northern region dummies are negative implying that farmers residing in these agro-ecological zones compared to the central region (the base region) are less productive. These results imply that regionally-specific factors, whether agro-ecological or due to other locational characteristics, play significant role in determining productivity levels of farmers.

5.0 Conclusions

The paper has investigated the productivity effects of agricultural extension services in Uganda. The descriptive show that 21% of farming households had accessed extension services from public and other providers. However, the larger proportion of households who had extension contact accessed it through routine and on demand form of extension provision (10%). The proportion of household who had access to agricultural extension on demand was 3% compared to 8 percent access through routine provision. Although the percentage of farmers who have extension contact appears to be small, a world bank in 1998 found out that when about 25% to 30% of farmers are in regular and direct contact with extension, the majority of farmers will be aware of the messages being disseminated through farmer to farmer interactions. Indeed, descriptive research findings show that the majority of farming households rely on radio and farmer to farmer for agriculture information. This indicates the need to reorient the agricultural information provision and see how other sources of agriculture information (radio, farmer to farmer, newspapers, and agricultural shows) can be harnessed to boost the current agriculture extension delivery systems. This will require adopting initiatives that have worked in other countries and service areas. For example, specialized use of local radios and recruitment of village extension farmers are some of the avenues that can exploited by the current extension service system to reach the majority of unreached and underserved farmers in Uganda.

Results of the treatment effect model show a significant effect of access to extension services on yield. This implied that on average farming households who had extension contact were more productive than farming households with no extension contact. The positive and statistically significant effect of extension access underscores the important role played by agricultural extension services in increasing production and productivity in farming systems in the country. Implementing the *ivtreatreg* stata command that take care of the selection into homogeneous and heterogeneous treatment, we estimated the average treatment effect (ATE), average treatment effects on the treated (ATET) and average treatment effects on the non-treated (ATENT). The ATE had a negative sign meaning that farming households who had extension contact would have been less productive if they had not got access to extension services. The negative average value of ATET (x) implies that farming households who had extension contact would on average produce less than one tonnes per acreage if they get more access to extension services. This demonstrate that more and more extension contacts between the farmer and extension agent may not result into higher productivity returns because of diminishing returns associated with more extension contact. The mean value of the ATENT(**x**) predict that on average farming households who had no extension contact would have been more productive if they had extension access. This underscores the marginal benefits of increasing farmer's access to extension and advisory services to unreached farmers. Therefore, government efforts to ensure that the majority of agricultural farmers are in direct contact with extension agents should be supported so as to improve and transform agricultural households in Uganda. This conclusion makes sense in Uganda where calls have been made to suspend public extension funding.

The results from crop productivity OLS estimates show that extension visit variable is positive and significant. This implies that the number of extension visits received by farmer impacts farmer productivity by 1.1 percent other factors kept constant. This is agreement with many studies in Africa that show positive impact of extension contact (Owen *et al*, 2001; Ragasa *et al*, 2012; Hasan *et al*, 2013). Using the two stage instrumental variable approach however, we found that number of extension visits do significantly affect farmers productivity positively at 10 percent level. We argued that access to agriculture extension services has positive favourable effect on farm productivity. Our analysis also reveals several other factors that significant in influencing extension contact and crop productivity such as managerial experience of the farmer, access to credit, irrigation and fertilizer use, education, gender, labour supply, level of commercialization, cultivated land, education , memberships to farmer group and locational factors.

Conclusively, the findings clearly support vast literature of the important role of extension contact in raising farmer's productivity and therefore matters if we are to improve the low productivity levels of farmers in Uganda. We recommend efforts geared at reforming the extension system so as enable the underserved and unreached farmers to access extension services. In particular, policy makers need to re-orient their efforts to strengthen the use of other channels such as mass media, ICT tools and farmer-to-farmer so as to reach as many farmers as possible in the demand driven extension system.

Appendix 1: Results from ivtreateg when probit-2SLS is the specified model and treatment heterogeneous response is assumed

Step 1: Probit regression			**Step 2: Instrumental variables (2SLS) regression**		
Access to extension services	**Coef.**	**p-value**	**Yield**	**Coef.**	**p-value**
Farmer_group_membership	1.039	0.000	access_extension	-0.618	0.488
No_plots	-0.001	0.220	_ws_credit_access	4.189	0.082
No_plots_sq	0.000	0.772	_ws_irrigation2	-81.251	0.179
Years of schooling	0.006	0.000	_ws_HHH_male	-1.125	0.438
Experience	0.001	0.263	_ws_Sch	0.013	0.807
Cultivated_land	0.042	0.000	_ws_experience	-0.001	0.979
Cultivated_land_sq	-0.001	0.000	_ws_fertilizer2	2.703	0.123
Family_labour	0.036	0.000	_ws_Cultivated_land	0.269	0.579
Hired_labour1	0.001	0.000	_ws_Cultivated_land_sq	0.013	0.507
Distance_market	0.000	0.997	_ws_family_labour	-0.669	0.210
Credit_access	0.307	0.000	_ws_hired_labour1	-0.037	0.218
Access_irrigation	0.199	0.005	_ws_D_local_mkt	0.038	0.400
HHH_male	0.030	0.197	No_plots	-0.036	0.000
Fertilizer_use	0.205	0.000	No_plots_sq	0.000	0.000
Constant	-1.446	0.000	Sch	0.012	0.263
Number of obs	30720		experience	0.014	0.273
LR chi2(13)	3760.46	0.000	Cultivated_land	-0.646	0.000
-	-	-	Cultivated_land_sq	0.011	0.058
-	-		family_labour	0.225	0.237
-	-	-	hired_labour1	0.019	0.243
-	-	-	D_local_mkt	-0.007	0.515
-	-	-	credit_access	-1.612	0.050
-	-	-	irrigation2	42.432	0.175
-	-	-	HHH_male	0.672	0.119
-	-	-	fertilizer2	-0.986	0.221
-	-	-	Constant	2.238	0.000
-	-	-	Number of obs	30720	0.003
-	-	-	F(25, 30694)	11.6	0.000
-	-	-		12.03	0.000

Appendix 2: Bootstrap results

Number of obs	30720			
Replications	100			
	Observed Coef.	Bootstrap Std. Err	Z	p-value
ATET	-0.68	1.20	-0.57	0.57
ATENT	-0.73	1.00	-0.73	0.46

Appendix 3: OLS and 2SLS estimates with extension routine and demand and commercialization dummies

	OLS		2SLS	
In_Yield	**Coef.**	**p-vlue**	**Coef.**	**p-value**
Number of extension visits	0.021	0.000	0.050	0.002
No_plots	-0.001	0.428	-0.001	0.423
No_plots_sq	0.000	0.024	0.000	0.016
Years of schooling	0.005	0.000	0.005	0.000
Experience	0.001	0.149	0.001	0.198
Cultivated_land	-0.255	0.000	-0.256	0.000
Cultivated_land_sq	0.004	0.000	0.004	0.000
Family_labour	0.068	0.000	0.065	0.000
Hired_labour1	0.001	0.007	0.001	0.014
Distance to market	-0.002	0.000	-0.002	0.000
HHgender_male	0.078	0.000	0.079	0.000
Fertilizer_use	0.129	0.000	0.117	0.000
Credit_access	0.081	0.001	0.059	0.034
Access_ irrigation	0.319	0.000	0.305	0.000
Farmer_farmer	-0.030	0.123	-0.019	0.341
Eastern region	-0.219	0.000	-0.221	0.000
Northern region	-0.796	0.000	-0.804	0.000
Western region	0.613	0.000	0.612	0.000
Constant	-0.599	0.000	-0.603	0.000
Number of obs	30720		Number of obs	30720
F(18, 30701)	501.69		Wald chi2(18)	9009.21
Prob > F	0.000		Prob > chi2	0.000
R-squared	0.2470		R-squared	0.2455

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