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Technological Change in Uganda's Agricultural Sector Between 2005-2010

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Abstract
The study estimates the rate of technological change in Uganda's agriculture during 2005-2010, and across the 4 major regions of the country. Using a nationally representative household panel data set, a time trend variable in the stochastic production frontier was used to account for hicks-neutral technological change. The frontier is then re-modelled using binary time trend dummy variables to capture the temporal pattern of technological change. Overall it was found that technological progress was small and insignificant of 0.031% but further decomposition at regional level revealed more interesting findings. The western region had technological progress at 0.6%, and the central region had technological regress of 0.57%, both significant at 5% level. The northern region had technological progress at 0.008% and the eastern region had technological regress of 0.11% both insignificant at 5% level. The findings suggest that more public and private investments in region-specific technology development would be required to accelerate technological progress especially in the northern and eastern regions of the country. Alternatively with the existing level of investment, effort should be made to address the institutional issues that constrain efficient dissemination of the technologies developed from the National Agricultural Research System.

Key words: Stochastic production frontier, Hicks-neutral technological change, Technological progress/regress.

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1. Introduction

In many parts of Africa, the major challenge facing agriculture is how to increase farm production to meet food changing needs without degrading the natural resource base. Growth in the agricultural sector continues to be the cornerstone of poverty reduction, because of the importance of the sector in overall GDP, export earnings and employment as well as its forward and backward linkages to the non-farm sector (Nkamleu, 2004). A key factor for a sustained increase of agricultural production is improvement of productivity. Productivity growth in agriculture sector is considered an important issue to the development process; allowing countries to produce more food at lower cost, improve nutrition and welfare, and release resources to other sectors (Singh and Singh, 2012). However, many African farmers are still using low yielding agricultural technologies, which lead to low productivity and production.

An important driver of productivity growth is technological change. Increased agricultural productivity and growth, driven by technology, has a powerful dynamic effect that benefits the poor throughout the economy: directly through increased agricultural income and employment, and indirectly through increased food availability and lower food prices as well as through the demand created by increased agricultural incomes for non-farm goods and services produced by the very large, employment intensive non-agricultural rural economy (Nkamleu, 2004). In Uganda, agriculture is a strategic sector, targeted for the transformation of the economy from a peasant to a modern prosperous society in 30 years (GoU 2010). It plays a dominant role in export earnings, contributing 85% of the country's total exports (MFPED, 2010), providing employment to about 66% of the labor force living in rural areas, and a livelihood to about 86% of the population (RoU, 2014).

Although the contribution of agriculture to Gross Domestic Product (GDP) at current market prices stands at 20.9%, the sector has contributed to the growth of the industrial sector whose contribution to overall GDP is estimated at 25.4%, through agro processing activities (RoU, 2015). Nonetheless, this means that the biggest proportion of Ugandans, 66%, who are employed by the sector, are less productive than the remaining 34% who contribute 79% to GDP. The performance of the sector therefore continues to be an issue of great policy concern where the major concern relates to overall agricultural productivity. Improving agricultural productivity however remains a challenge for the government of Uganda despite numerous policy reforms undertaken in the sector in the recent past and donor development assistance that has been invested in increasing productivity at the household level. Despite these efforts, poverty in the rural agricultural dependent households has risen which poses a challenge on how to continue to address this problem. Technological change is one of the avenues that are believed can contribute to increases in productivity by modernizing the agriculture sector in Uganda.

Agricultural technology development in Uganda is the responsibility of the National Agricultural Research System (NARS) under the National Agricultural Research Organization (NARO). The National Agricultural Research Policy of 2003 provides for the establishment of NARO to take charge of all matters concerning agricultural research in Uganda including technology development (MAAIF, 2004). It is through research that technologies are developed. NARO through its regional subsidiaries, the zonal agricultural research and development institutes (ZARDIs) develops research priorities for the different regions, develops technologies, undertakes on-station demonstrations, and on-farm trials. In the context of NAADS, agricultural technology development is defined as a process of introducing, multiplying, adapting and disseminating recommended practices, methods, approaches, items or products of a given enterprise. The aim of agricultural technology development is to stimulate a demand for crop and livestock related technologies and to increase rates of adoption among targeted farmers. Technology Development Sites (TDS) are expected to be established as prime locations in the community where farmer groups learn new technologies and skills, and access improved crop and livestock inputs. The technologies are obtained from the NARS as well as any other private research partners. TDS are regarded as critical to successful agricultural advisory services and a major factor contributing to farmer adoption, and subsequently, increased production and yields (ITAD, 2008). During the period of this study, NAADS implementation made progress and had covered about 80% of the country with 45,000 TDS by 2010.

The performance of the agricultural sector can be evaluated by identifying the sources of output growth. In general, output growth is attributed to movements along a path on or beneath the production frontier (size effect), to movements toward or away from the production frontier (changes in technical efficiency), and to shifts of the production frontier or technological change (Giannakas et al, 2001; Si and Wang, 2011). Technological change can be defined as a shift in the production function with all input quantities held constant (Karagiannis et al, 1999). It can also defined as the change in the best practice production frontier (Nishimizu and Page 1982). The shift may be outward (technical progress) or inward toward the origin (technical regress). Technological progress, as defined by Nishimizu and Page, 1982, is the consequence of innovation or adoption of new technology by best practice firms. There is accumulating evidence that the productivity gain due to improvements in technical efficiency is substantial in developing economies, and may out-weigh gains from technological progress. This is often attributed to a lack of ability and/or willingness to adjust input levels on the part of producers, due to familiarity with traditional agricultural systems and/or the presence of institutional and cultural constraints (Ghatak and Ingerset, 1984). Yet the introduction and continuous creation of new technology is often used as a standard for distinguishing a modem agricultural system from a traditional system (Schultz, 1964). With efforts to modernize Uganda's agriculture, it is important to know how far the sector is off the technological frontier at any point in time, and how quickly it can reach the frontier.

The purpose of this paper is to investigate the rate of technological change in the country during the period 2005-2010. Specifically, the rate of technological change is estimated for the country data and for each of the four regions; central, eastern, northern and western, for the entire study period. The paper also tracks the resultant partial effects of technological change on agricultural output across the time periods. The paper provides evidence using two national panel data sets, 2005/06 and 2009/10, collected by the Uganda Bureau of Statistics (UBOS) and representative of the heterogeneity in the country. Past studies have been limited both in scope and representativeness hence their findings have limited external validity. For example Nabbumba and Bahiigwa, 2003 explore the profitability and productivity of two technologies; improved maize varieties and improved cattle breeds using household data from four rural districts selected from the banana-coffee, and the northern farming systems. Although they find that the improved technologies are found to be more profitable and productive, and recommend the wide promotion

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of the adoption of improved technologies, they point out that it is important to know whether technical progress is stagnant over time and whether a given technology is being used in such a way as to realize its full potential. Ainembabazi *et al*, 2005 examine the nature of technological change in sorghum production between improved technology and traditional technology using cost-function analysis in eastern Uganda. Their results indicate that farmers using improved sorghum use higher quantities of factors of production and therefore incur higher costs of production compared to farmers using traditional sorghum technology. However the production function was found not to have undergone structural change between traditional and improved technologies.

Using the same national data set, Kasirye, 2013 examines the determinants of improved agricultural technologies adoption, considering two agricultural technologies—improved seeds and fertilizer and finds that farmers with low education and land holdings are less likely to adopt improved seeds and fertilizer, while peer effects play a big role in influencing farmers to either use improved seeds or fertilizer. While past studies mainly used cross sectional data with its inherent econometric issues, this is the first study to use panel data in assessing technological change in Uganda.

The remainder of this study is organized in four major sections as follows. Section two gives materials and methods. Section three presents and discusses empirical results. Section four concludes.

2. Materials and Methods

2.1 Data

The study utilizes the Uganda National Panel Survey (UNPS) data sets of the years 2005/06, and 2009/10 collected by the Uganda Bureau of Statistics (UBOS). This national data is collected at household and community levels for two cropping seasons in each year. The two cropping seasons in the two years constitute four time periods for this study (i.e season 1 05/06, season 2, 05/06, season 1 09/10 and season 2, 09/10 are time periods 1, 2, 3, and 4 respectively). Agriculture in Uganda consists mainly of mixed farming in cash crops, food crops and livestock. The data that was obtained for this study was for the various food crops cultivated in the four regions of the country; central, eastern, northern and western, during the four time periods. These include bananas (*matooke*), maize, beans, millet, cassava, potatoes, sorghum. According to the data available, the inputs of production that are considered in the study are; the land specifically the acreage under the crop or plot size, labor (both family and hired in person-hours), whether a household used organic, inorganic fertilizers, and chemicals (pesticides and herbicides).

Land is recognized to be one of the most important factors of production used in the growing of crops. The pattern of land use varies by season and by region, and hence the area under crops may vary from time to time. The area under the different crops grown in a given season was estimated by the farmer, in acres, and the total area for each household is recorded as *crop area*. The amount of labor time hired by the household (*hlab*) and that used by the household members (*flab*) for the different tasks in crop production was collected in person days. A person day, according to UBOS, 2009 is a measurement that is used to reflect the total amount of time that a team spends full time in any activity. Further, labor time was segregated into men's, women, and children's labor. Battese and Coelli, 1996 convert labor hours to male equivalent units according to the rule that female and child hours were considered equivalent to 0.75 and 0.5 male hours respectively. Labor time was accordingly converted and added up to get the total hired labor time ($hlab_{it}$) and family labor time ($flab_{it}$) for an individual household, i at a given time period *t*.

The agricultural inputs used in crop production also include fertilizers which are divided into the inorganic and organic fertilizers. Inorganic or chemical fertilizers are divided into four types; the nitrogenous, potash, phosphate and mixed complex fertilizers, while the organic fertilizers include farm yard manure, compost, green manure and seaweed. Chemicals include insecticides, fungicides, herbicides and pesticides. The amount of harvest from each crop that the farmer planted on the recorded crop area was estimated in various local measurements, and later converted to kilograms. The quantity of produce (*qty*) used in the model is therefore an aggregate of the different quantities of crop harvested by the household in the respective time periods. The value of output was then obtained by getting the output reported by the farmer and valuing it using 2005 prices.

2.2 Estimation methods

The stochastic frontier production function methodology is used to describe the production of the Ugandan farming households. The estimation of technological change follows specifically the model proposed by Battese and Coelli, 1995 for panel data. Battese and Coelli, 1995 define a stochastic frontier production function for panel data on firms, in which they take technological change into consideration by including the *year* variable among the explanatory variables. This assumes the presence of Hicks-neutral technological change.
The model proposed by Battese and Coelli, 1995 for panel data is defined by;

$$Y_{it} = \exp(x_{it}\beta + v_{it} - u_{it}) \quad (1)$$

Where Y_{it} denotes production at the *t-th* observation (*t = 1, 2, 3.....T*) of the *i-th* firm (*i = 1, 2, 3....N)* x_{it} is a *(1 x k)* vector of values of known functions of inputs of production and other explanatory variables associated with the *i-th* firm at the *t-th* observation, β is a *(k x 1)* vector of unknown parameters to be estimated, v_{it} are assumed to be *iid* $N(0,\sigma_v^2)$ random errors, independently distributed of the $u_{it}s$. The u_{it}s are non-negative random variables, associated with technical inefficiency of production, which are assumed to be independently distributed, such that u_{it} is obtained by truncation (at zero) of the normal distribution with mean, $z_{it}\delta$ and variance, σ^2.Following the specification by Battese and Coelli 1995 above, the stochastic frontier production function model that is specified for the Ugandan farming households is defined below;

$$\ln(Y_{it}) = \beta_0 + \beta_1(org)_{it} + \beta_2(Inorg)_{it} + \beta_3(pest)_{it} + \beta_4 \ln(croparea)_{it} + \beta_5(Hlab)_{it} + \beta_6(Flab)_{it} + \beta_7(Year_{it}) + v_{it} - u_{it} \quad (2)$$

Where $\ln$ represents the natural logarithm (i.e to the base *e*), Y_{it} represents the total quantity of output from the various food crops harvested by the *i-th* farmer at the *t-th* observation, and measured in kilograms, org represents a dummy of the response on whether the household used organic fertilizer or not, so that *org*=1 if yes, and *org*=0 if otherwise, $In\,org$ represents a dummy of the response on whether the household used inorganic fertilizer or not, so that *inorg*=1 if yes, and *inorg*=0 if otherwise, *pest* represents a dummy of the response on whether the household used pesticides, herbicides, and other chemicals, or not, so that *pest*=1 if yes, and *pest*=0 if otherwise, *croparea* represents the total area in acres under the food crops harvested, *Hlab* represents number of person days of hired labour, *Flab* represents number of person days of family labour, *Year* represents the time period of the observation (expressed in terms of 1, 2, 3, 4), $\beta_0......\beta_7$ are unknown parameters to be estimated.

The change in output with respect to time is considered to be a result of the change in technical efficiencies, change in output elasticities, as well as technological change (Page and Nishimizu, 1982; Si and Wang, 2011). Technological change is obtained by including a time variable in the specified model, so that when the change in output over time is decomposed into these constituent components, technological change can be obtained as follows;

$$TC_{it} = \frac{\delta \ln f(X_{it}t;\beta)}{\delta t} \quad (3)$$

Where TC_{it} is the technological change of the *i-th* household in time period *t*, X_{it} is a vector of input variables, and β is a vector of unknown parameters to be estimated as in equation 3. The coefficient on the *year* variable, β_7, in equation 3 is therefore expected to be a measure of technological change. The model is estimated using the FRONTIER 4.1 program.

The measure of technological change thus obtained is one measure for the entire period of study. However Karagiannis (1999) on models of technical change, proposes that technical change can be modeled differently by using time dummies to capture its temporal pattern. Assuming a fixed intercept in each region but which can vary across the regions, and taking the first time period as the reference period (Gujarati, 2004), binary time trend dummies are introduced to the model. In a given region, the model has been specified as follows;

$$\ln Y_{it} = \alpha_0 + \alpha_1(org) + \alpha_2(inorg) + \alpha_3(pest) + \alpha_4(\ln area) + \alpha_5(Hlab) + \alpha_6(Flab) + \alpha_7(D_{2i}) + \alpha_8(D_{3i}) + \alpha_9(D_{4i}) + v_{it} - u_{it} \quad (4)$$

Where D_{2i} =1 if the observation in the given region belongs to time period 2, 0 otherwise, $D_{3i} = 1$ if the observation in the given region belongs to time period 3, 0 otherwise, $D_{4i} = 1$ if the observation in the given region belongs to time period 4, 0 otherwise, $\alpha_0 ... \alpha_9$ are unknown parameters to be estimated while the rest of the variables remain as described in 4.

Three time dummies are used in order to avoid the dummy-variable trap, a situation of perfect collinearity (Gujarati, 2004), and time period 1 is used as the reference period for each region. The intercept term α_0, therefore, is the logarithm of the median output of the region in time period 1. The coefficients $\alpha_7, \alpha_8, \alpha_9$, are logarithms of the difference between the median output of time period 1 and the respective time periods. Finding the antilog of the respective coefficients gives the values in the original units (kgs).

The variables representing these inputs; *inorg, org, and pest* are dummies as households were responding whether they used them or not. Each of them is expected to have a positive effect on the quantity harvested. The type of seed used are commonly local seed obtained locally and normally of local varieties. Improved/hybrid seed are mostly and obtained by farmers from shops. Improved seed is expected to have a positive effect on quantity harvested. As crop area increases, the total quantity harvested is expected to increase. The variable *crop area* is therefore expected to have a positive sign. *hlab* is expected to have a positive effect on quantity harvested since the few households that are able to hire labor are also in better position to employ other yield enhancing technologies such as fertilizers. On the other hand, *flab* is expected to have a negative effect as more families are not necessarily likely to be more productive. The *year* variable represents the time period of a given observation as explained above. In the main model (4) it is expected that technological changes occurred over the period of study and so the coefficient may be positive or negative.

2.3 Hypothesis Testing

In order to test for the presence of technical change, tests of the hypothesis were first carried out on the regional and country data. The tests are performed using the generalized likelihood-ratio test statistic, λ defined by;

$$\lambda = -2 \ln[L(H_0)/L(H_1)] \qquad (5)$$

Where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. If the null hypothesis is true, the test statistic has approximately a chi-square or a mixed chi-square distribution with degrees of freedom equal to the number of restrictions in the null hypothesis (Gujarati, 2004).

3. Results and Discussion

3.1 The use of improved Inputs

The use of improved inputs by the farming households in the country was found to be very low. The proportion of households for each regional sample, using various inputs is shown in Table 1.

Table 1: Input use during the study period among the regions

Inputs	Time Period			
	1	2	3	4
Central Region				
Hired Labour (persondays)	0	0	5.2	3.36
Chemicals (%)	9.18	20.4	16.3	12.24
Inorganic fertiliser (%)	6.1	16.32	12.2	17.3
Organic fertiliser (%)	8.16	19.38	15.3	19.38
Improved seed (%)	5.1	5.1	5.1	4.08
Crop area (acres)	2.35	2.71	2.46	2.37
Value of output ('000 shs)/acre	38.1	24.3	13.15	23.8
Sample size	98	98	98	98
Eastern Region				
Hired Labour (persondays)	0	0	7.04	1.72
Chemicals (%)	4.08	9.18	9.18	12.95
Inorganic fertiliser (%)	3.06	9.18	7.14	12.25
Organic fertiliser (%)	7.14	15.31	10.2	15.31
Improved seed (%)	14.28	6.12	6.12	4.08
Crop area (acres)	1.59	1.81	2.06	1.69
Value of output ('000 shs)/acre	48.6	36.7	23.15	20.47
Sample size	98	98	98	98
Northern Region				
Hired Labour (persondays)	0	0	2.56	3.3
Chemicals (%)	18.51	11.22	15.74	10.18
Inorganic fertiliser (%)	18.51	7.4	13.89	10.18
Organic fertiliser (%)	15.74	13.88	14.53	11.11
Improved seed (%)	7.4	4.62	5.55	5.55
Crop area (acres)	2.12	1.93	2.12	1.77
Value of output ('000 shs)/acre	46.53	30.58	30.42	17.18
Sample size	108	108	108	108
Western Region				

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Hired Labour (persondays)	0	0	2.53	6.04
Chemicals (%)	3.3	13.33	10	10
Inorganic fertiliser (%)	5	13.33	5	16.67
Organic fertiliser (%)	10	15	10	10
Improved seed (%)	3.33	5	8.33	11.66
Crop area (acres)	0.93	1.61	1.74	1.49
Value of output ('000 shs)/acre	13.69	17.65	18.06	21.68
Sample size	60	60	60	60
Uganda				
Hired Labour (persondays)	0	0	4.48	3.34
Chemicals (%)	9.61	13.18	13.19	11.45
Inorganic fertiliser (%)	8.79	11.26	10.16	13.73
Organic fertiliser (%)	10.43	15.93	12.82	14.29
Improved seed (%)	7.96	5.22	6.04	5.77
Crop area (acres)	1.84	2.06	2.14	1.82
Value of output ('000 shs)/acre	39.39	28.42	21.78	20.58
Sample size	364	364	364	364

The findings show that across the four regions and in the country sample, the number of households using improved seed/planting material is the least. The proportion of households using organic fertilizer is higher than those that use other inputs in all the regions. The central region has higher proportions of households using both inorganic fertilizer and chemicals than other regions, while the eastern region has greater variation in the proportions of household using the two across time periods. The greater use of both inorganic fertilizer and chemicals in the central region is perhaps linked to greater availability of markets for the two inputs in the region.

3.2 Technological change across the regions

Technological change is modeled in two ways; the first is by including the year of observation as a simple time trend in the production function as in Battese and Coelli 1995, while the second is by using multiple time trend variables as in Karagiannis *et al*, 1999. Using the simple time trend assumes the possibility of Hicks-neutral technical change. The coefficient of the *year* variable β_7, in equation 2, therefore represents technological change, which can also be obtained with equation 3. Using the multiple time trend variables in equation 4 enables the segregation of the effects of technical change of the entire study period into the different time periods. However, tests of the hypothesis were first carried out on the regional and country data to test for the presence of technical change. The results of the tests are shown in Table 2 below.

Table 2 Tests of Hypotheses of no technical change

Null Hypothesis	Log-Likelihood Function	Test Statistic λ	Critical Value χ^2	Decision
$H_0 : \beta_7 = 0$				
Central	-702.29	1.7	3.84	Accept H_0
Eastern	-739.48	6.8	3.84	Reject H_0
Northern	-825.10	1.9	3.84	Accept H_0
Western	-413.53	6.36	3.84	Reject H_0
Uganda	-2699.17	10.9	3.84	Reject H_0

Source: Author calculations from UBOS panel data sets, 2005/06 and 2009/10)

The hypothesis of no technical change cannot be rejected for the central and the northern regions, but it is rejected for the eastern and western regions, as well as the country data for the study period.

The partial effects of technological change

The maximum likelihood estimates of the parameters ($\beta_1 .....\beta_6$) of the stochastic frontier model (2) are presented in Kalibwani et al, 2014. The coefficient on the *year* variable, β_7, in equation 3 is the measure of technological change. The maximum likelihood estimates of the parameters for technological change in the stochastic frontier model for the four regions are therefore presented in Table 3 and subsequently discussed.

Table 3 Maximum Likelihood Estimates for the parameters of technical change across the four regions

Region	Parameter	Coefficient	t-ratio
Central	β_7	-0.57**	-1.97
Eastern	β_7	-0.11	-0.46
Northern	β_7	0.008	0.095
Western	β_7	0.60**	2.2
Uganda	β_7	-0.031	-0.63

Notes: ** Significant at 5% level
(Source: Author calculations from UBOS panel data sets, 2005/06 and 2009/10)

The coefficient of the *year* variable is negative for the central and eastern regions as well as the country data implying technical regress over the study period. The coefficient is significant at 5% only for the central region. It shows that there was 0.57% technical regress in the central region over the study period. For the northern and western regions, there was technical progress. There was 0.6% technical progress in the western region which was significant at the 5% level. The effects of technical change on the output of the different regions in the different time periods are obtained after using the multiple time trend variables which are also binary time variables in model (4). The results are presented in Table 4.

Table 4 Maximum Likelihood Estimates of the time trend parameters for the four regions

		Time Periods	(Coefficient)	
Region	**1**	**2**	**3**	**4**
Central	3.596***	-0.13	-1.04	-1.03
	(6)	(-0.33)	-(1.54)	(-1.19)
Eastern	2.37***	-0.18	0.07	0.004
	(6.01)	(-0.18)	(0.07)	(0.004)
Northern	2.3062***	0.042	-0.17	0.50*
	(12.61)	(0.19)	(-0.64)	(1.52)
Western	2.707***	0.559	1.02*	2.28**
	(5.19)	(1.44)	-1.61	(2.2)
Uganda	2.39***	-0.070	-0.366***	-0.15
	(23.94)	(-0.43)	(-4.49)	(-1.19)

Notes: ***Significant at the 1% level, **Significant at 5% level, * significant at 10% level)
(Source: Author calculations from UBOS panel data sets, 2005/06 and 2009/10)

The values obtained in Table 4 are natural logs of the actual coefficients. The antilogs of these values are obtained and interpreted as follows. The antilog of α_0 is the median output value of time period 1 in the respective region, while the antilogs of the rest of the coefficients $(\alpha_7, \alpha_8, \alpha_9)$ show the difference between the median output of time period 1 and the median output of the respective time period of the respective region (Gujarati, 2004). The antilogs of the values in Table 4 are presented in Table 5 and used to illustrate the effect of technological change over time in figure 1.

Table 5 Difference from median output of 2005 for subsequent time periods per region

Region	Median Output of in'05(kg)	Differences(kg)		
		'06	'09	'10
Central	36.48	-1.14	-2.83	-2.79
Eastern	10.71	-1.19	1.07	1.003
Northern	10.036	1.043	-1.193	1.651
Western	14.977	1.749	2.8	9.872
Uganda	10.951	-1.073	-1.442	-1.169

(Source: Author calculations from UBOS panel data sets, 2005/06 and 2009/10)

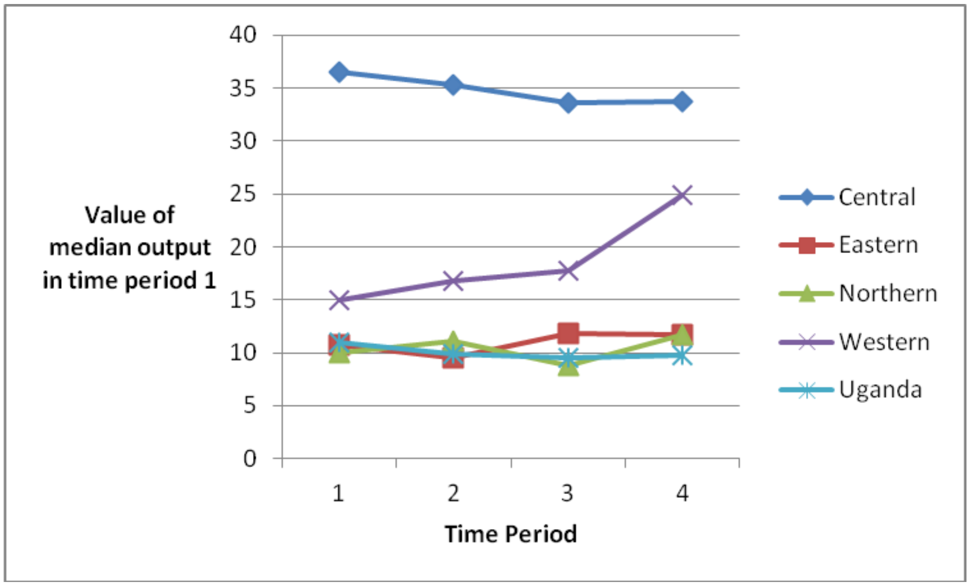

Figure 1: The effect of technological change on value of median output of time period 1 per region
Source: Author calculations from UBOS panel data sets, 2005/06 and 2009/10

Technological change in Uganda's agriculture is to a large extent a function of the NARS, the NAADS and the private agencies that are involved in technology development and dissemination. Although the study was not able to capture households participating in NAADS activities, implementation of the NAADS program is reported to have gained momentum during this period with beneficial effects on both NAADS and non-NAADs households countrywide (ITAD, 2008). Between 2001 and 2010, the program achieved countrywide roll-out, covering 79 districts, 1,066 sub-counties, with over 45,000 TDS having been established and managed by farmers with the help of researchers and service providers, for training and expediting technology (PCD 2012). Technological change across the regions therefore is contributed to by these developments although it was not possible to establish to what extent.

For the central region, the hypothesis of no technical change cannot be rejected, but the year variable is a significant component of the model for the central region. The coefficient of the *year* variable indicates that there was 0.57% technical regress which was statistically significant at 5%. The technical regress caused a consistent decline on average in median output. The findings imply that there was no significant adoption of new technologies and with the existing level of technology use, median output levels significantly declined. The central region has higher proportions of households using both inorganic fertilizer and chemicals than other regions (Table 1) however these do not translate into improved technical change for the region. The central region of the country is covered in part by the Lake Victoria crescent, one of the areas that has been identified as hotspot of land degradation. Although originally regarded as high productivity area, nutrient depletion and hence soil infertility were reported to be a problem (NEMA 2010). It is possible that with this nutrient depletion in the soils, the use of improved inputs could not improve yields in the region, but cause a significant reduction. Alternatively, there could be other factors beyond the control of the farmers that contributed to this reduction. Such factors include pests and diseases specific to certain food crops. In particular, Komarek 2010 observes for bananas in the central region, that there were yield losses associated with banana weevil, banana bacterial wilt, nematodes and black *sigatoka* in the period 2005-07, that needed to be addressed by the distribution of new technologies developed by NARO.

Komarek 2010 also observes the loss of soil fertility in the region during the same period as causing yield losses in bananas. The central region was reported to be the second largest producing region of bananas in the country next to the western region according to UBOS 2011 and banana is a major food crop for the central region. Another important factor for the central region is labour migrating from agriculture with increasing opportunity cost elsewhere. Given the unique geographical location of the region that provides access to other lucrative opportunities in and around the city, the proportion of the labor force working in the informal sector and outside of agriculture is highest in the central region at 60.3% (UBOS, 2010). This might be a challenge in attaining technical progress in agricultural production in the central region. Si and Wang, 2011 find the same challenge for China's soya bean sector.

In the eastern region, the hypothesis of no technical change is rejected even at 1% level although the coefficient of the *year* variable in the model shows technical regress of 0.11% which is not significant. Variations of the median output levels in the subsequent periods from the median output level of 2005 may have been substantial but overall leading to decreased output levels for the entire period as shown in table 5 and figure 6. Although Uganda as a country is highly vulnerable to climate variability, where climate events result in droughts, floods and land slides, the eastern region for a period of 10 years (2001-2010) was noted by NEMA 2010 to be especially prone to floods. If floods occur particularly during the major cropping season, they have serious consequences on the key crops and communities are less able to obtain them (NEMA 2010). The eastern region was noted to have significant agricultural potential in the crops specific to the region and the leading producing region of finger millet, maize, sorghum and rice. However it is possible that floods at anyone time could out do the positive effects on production of any technological advancement when it does occur, and production only recovers when floods do not occur. Such variations could account for the observed variation in median output levels from the benchmark median level of 2005.

For the northern region, variations in median output levels from the benchmark of 2005 are not substantial. The results show that there was technical progress in the region which was not significant, and the hypothesis of no technical change could not be rejected. The northern region is sparsely populated, and the least populated of the four regions. Endowed with the most productive land in the country, the per capita land size is largest in the northern region. The sparse population may therefore partly explain the lack of substantial change in median output levels which would have captured technical change. On the contrary in another study (Kalibwani, 2013) the northern region is found to have impressive technical efficiency scores when compared to the rest of the regions. This is not uncommon as Nishimizu and Page 1982 point out that relatively low rate of technical progress can co-exist with rapidly improving technical efficiency. None the less, the resettlement program of the population of northern Uganda after a decade of conflicts and subsequent introduction of the NUSAF program, is likely to have made a good contribution to the observed technical progress.

For the western region, the hypothesis of no technical change is rejected even at 1% level. The findings indicate technical progress in the region of 0.6% which is statistically significant at 5% level. Table 5 and figure 6 both indicate steady technical progress in the region between 2005 and 2009, and a sharp acceleration up to 2010. The western region is one of the regions that are densely populated and with good access to extension service providers and markets. These factors could explain the adoption of technologies that is reflected in the technical progress observed during the study period. Furthermore Mbowa *et al*, 2012 use the same dataset for the western region, and find specifically for the diary industry that technological progress in the industry was due to increased number of households adopting new technologies mainly the improved breeds of cattle. Unfortunately, the observed technical progress in this study does not translate into improved productivity and technical efficiency in the region (Kalibwani *et al*, 2014). This is perhaps due to other factors already pointed out such as land degradation which might work against the improvement in productivity due to technical progress. Kasirye, 2013 finds specifically for the western region that cattle keeping farmers are more likely to abandon fertilizers and possibly resort to organic manure from livestock excreta. It is also possible, as Nishimizu and Page 1982 point out that farmers may adopt technologies but there are failures in achieving technological mastery or, as Giannakas *et al*, 2001 observe, fail to fully utilize them due to lack of proper instruction and risk aversion tendencies.

For the country sample, the findings show that technical change is a major component of the production function and therefore the hypothesis of no technical change is strongly rejected. The coefficient of the *year* variable however shows that overall there was a 0.031% technical regress in the country sample which was not significant. It is also clear from the country sample that the median output value decreases slightly between 2009 and 2010 indicating a decline in technical change in the country during that period. Although specific factors could have affected different regions, MFPED 2010 observes that prolonged rainfall and improved international food crop prices provided incentive for production in many parts of the country from the first season of 2009 to the second season of 2010. This is likely to have contributed to the slight improvement in technical change in the country data. Specifically the western and northern regions had the most contribution to technical progress, while the central and the eastern regions contributed to technical regress in the country during the study period.

In spite of the regional variations, there are institutional factors that could contribute to the observed technical change in the country. ITAD 2008 observes that the challenges with operating the TDS include the timing of input provision, the quality and price of inputs and accessibility of the TDS. If inputs, particularly for agricultural TDSs, arrive late in the growing season this greatly affects the extent to which farmers can learn from both process and output demonstration, while on occasion inputs are of poor quality (ITAD 2008).

4. Summary and Conclusions

This study finds that there was technical regress of 0.031% in agricultural production in the country sample, which was not statistically significant. There were however regional differences. The western region had technical progress of 0.6% significant at 5% level, followed by the northern region at 0.008% but was not significant. The central region had technical regress of 0.57% significant at 5% followed by the eastern region, technical regress of 0.11% which was not significant.

The factors thought to contribute to these differences vary with the region. In the western region, the dense population and adoption of the technologies disseminated in the NARS might have been responsible for the technical progress, while in the northern region, government effort to resettle the population and support agricultural activities through the NUSAF program might have supported technical progress. In the central region, the proportion of the labor force engaged outside of agriculture (60%) is high and the labor migration from agriculture to other more lucrative opportunities seems to pause a challenge for technical progress in the region in addition to nutrient depletion from the soils. The eastern region notably experienced frequent floods during the period possibly causing the fluctuations in technological change and subsequent technical regress.

The model used in the study does not incorporate the factors discussed above in order to ascertain the extent to which they might have influenced the observed technological change. Further research would be required in order to confirm their impact on technical change in the different regions. What is clear is that there was mild technological regress and subsequent contribution to output growth in the country's agriculture during the study period. The findings suggest that more investment in research for technology development would be required to enhance technological change. Alternatively at the existing level of investment, the institutional issues that constrain efficient technology dissemination should be addressed. Furthermore, the study supports technology development that is based on the specific regional differences in the country to take into consideration the variations that do exist across regions.

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