J. Agr. Sci. Tech. (2011) Vol. 13: 1-15

Agricultural Science and Technology Policy System Institutions and Their Impact on Efficiency and Technical Progress in Kenya and Uganda

G. L. Mugunieri[1*], S. W. Omamo[2], and G. A. Obare[3]

ABSTRACT

Results of an evaluation of the impact of agricultural science and technology (AS and T) policy system institutions on efficiency and technical change in Kenyan and Ugandan agriculture are presented here. Data envelopment analysis was used to derive efficiency and technical change and logistic regression applied to delineate AS and T institutions that induced efficiency and technical progress. Technical progress was positively influenced by transboundary technology transfer, decentralization of extension services, thematic agricultural research and the literacy rate of the agricultural labour force. The intellectual property rights regulatory system negatively impacted on technical progress. On the other hand, efficiency progress was supported by the enactment of a regulatory framework for intellectual property rights system, but negatively influenced by transboundary technology transfer and decentralization of extension services.

Keywords: Agricultural science and technology policy, Kenya, Uganda**.**

INTRODUCTION

Background and Justification

The agricultural science and technology (AS and T) policy system is an important tool that governments can use to stimulate agricultural productivity growth (World Bank-FAO-WHO-UNEP, 2003). However, little is known about the structure of this policy system in developing countries. More intriguing, a precise definition of the policy system is difficult to locate in the literature. Recent reviews have either focused on agricultural research policy (Pardey *et al.,* 1991; Omamo *et al.,* 2000) or on agricultural science policy (Alston *et al.,* 1995; Alston *et al.,* 2001). By building on a description of agricultural research policy provided by Omamo *et al.* (2000), AS and T policy system can be defined as comprising structures and processes for setting priorities, specifying agendas, financing, organising, delivering, monitoring, evaluating, and assessing impacts of agricultural research, extension, education, and transboundary technology and information acquisition and exchange. A salient feature of this definition is that the policy system can be divided into four distinct but related system components, namely: research; extension; education; and transboundary technology transfer.

Omamo and Naseem (2005) observe that, within each system component, are found three cascading levels of shift effects, namely: (i) the policy environment; (ii) the institutional arrangements; and (iii) the ensuing micro-level conditions. This gives a

[1] Socioeconomics and Biometrics Programme, Kenya Agricultural Research Institute, TRC Center, P. O. Box: 362 Kikuyu, 00902 Kenya.
[*] Corresponding author; e-mail: lgodiah@yahoo.com
[2] United Nations World Food Programme, Via C.G.Viola 68, Parco dei Medici, 00148, Rome, Italy.
[3] Department of Agricultural Economics, Egerton University, P. O. Box: 536, Egerton, 20107 Kenya.

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

Table 1. Effects of AS and T policy system components and shifts.

		Agricultural S and T policy system components			
		Research	Extension	Education	Trans-boundary technology transfer
Agricultural S and T policy system shift effects	Policy Environment	Agricultural research financing policies	Agricultural extension financing policies	Agricultural education financing policies	Degree of economic openness
	Institutional arrangement	Regulatory framework for coordination of agricultural research	Extension delivery framework	Education access and quality control systems	Regulatory framework for intellectual property rights
	Micro-conditions	Number of technologies developed	Farmer-extension agent contact	Literacy level within the agricultural labour force	Transaction costs in accessing technologies

3×4 matrix of the potential policy system structure (Table 1). This paper focuses specifically on the nature, form and impact of the AS and T policy system's institutional arrangements on agricultural productivity growth in developing countries using Kenya and Uganda as case studies. It is envisaged that the results will inform us on ways that meso-institutions can be reformed to accelerate productivity growth and reduce poverty.

Conceptual Framework

Agricultural science and technology policy was conceived to contribute to agricultural productivity growth through its impact on technical efficiency and technical change (Kalirajan *et al.,* 1996). Technical efficiency represented the degree to which a country was able to convert its inputs efficiently into outputs, relative to the frontier. Technical change measured the extent to which the production frontier, representing the state of technology in a particular time period, shifted upwards over time, reflecting the application of new technologies. Therefore, technical change was used to delineate the impact that the AS and T policy system's institutional changes have had in facilitating the uptake of new technologies, whereas efficiency change was used to outline the impact of these institutional changes in enhancing the efficient conversion of inputs to outputs.

The impact of AS and T policy systems institutions on technical and efficiency change was envisaged to occur in two ways. First, by increasing access to innovations through research and transboundary acquisition and, secondly, by creating an environment that fostered learning by countries for effective application of these innovations. This nested innovation generation-cum-learning conceptual approach is closely linked to Malerba's general framework on incremental technical change arising from the learning process (Malerba, 1992). This framework presupposes that countries learn in a variety of ways and the learning processes lead to enhancement of their stock of knowledge and technological capabilities. Therefore, the prevailing AS and T policy will promote learning by countries that, in turn, generates a whole range of trajectories of efficiency and technological advances leading to increased productivity.

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

METHODOLOGY

The Malmquist productivity index was estimated and decomposed into technical efficiency change and technical change. According to Caves *et al.* (1982), an output-based *MI* with reference to the technology in time *t* is presented as:

$$MI_o^t = \frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad (1$$

And, subsequently, the output-based index with reference the technology in time period *t+1* is:

$$MI_o^{t+1} = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)} \quad (2$$

where D_0 represents the output distance function for time *t* and *t+1*, and *x* is a vector of inputs used to produce a vector of outputs, *y*.

Färe *et al.* (1992) defined the output-based Malmquist productivity index as the geometric mean of the two indices specified above as:

$$MI_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2} \quad (3$$

This index can be decomposed into two components, i.e.:

$$MI_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})}\right)\left(\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2} \quad (4$$

The first component (outside brackets) measures efficiency change, i.e. how the position of a production unit has changed relative to the frontier between the periods *t* and *t+1*. The second component (inside brackets) represents the technical change, that is how the frontier has shifted between the periods *t* and *t+1*.

The output distance function was computed for each production unit at time *t* under the assumption of constant return to scale, as a solution to the following data envelopment analysis (DEA) linear programming problems:

$$\begin{aligned} &(D_o^t(x^{k_i,t}, y^{k_i,t}))^{-1} = Maximise\,\theta^{k_i} \\ &Subject\ to: \theta^{k_i} y_m^{k_i,t} \le \sum_{k=1}^{K} \lambda^{k,t} y_m^{k,t} \\ &\sum_{k=1}^{K} \lambda^{k,t} x_n^{k,t} \le x_n^{k_i,t} \\ &\lambda^{k,t} \ge 0. \end{aligned} \quad (5$$

where θ^{k_i} is the DEA measurement of the $D_o^t(x^t, y^t)$ for production unit *k* in time *t*. The computation of $D_o^{t+1}(x^{t+1}, y^{t+1})$ under the assumption of CRS followed the same procedure with the only difference being the substitution of *t* with *t+1*.

Using these models the approach of Färe *et al.* (1994), it was thus possible to obtain the technological change (P) and efficiency change (E) for each country for each year. Interpretation of the technological and efficiency change indexes was that technical/efficiency progress (regress) had occurred if *P* and *E* were greater (less) than one. The indicators were derived using DEAP Version 2.1 (Coelli, 1996). Twenty-one countries from sub-Saharan Africa were purposively selected and used as peers in the DEA application so as to avoid any problem of dimensionality.

A logistic regression was subsequently used to capture the relationship between the direction of technical and efficiency change and the specific innovations within the agricultural science and technology policy system in Kenya and Uganda. The regression model was of the general form

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

Table 2. Input and output levels in Kenya and Uganda.

Variable	Kenya	Uganda
Inputs (Means)		
Fertilizers (NPK-nutrient tones)	90,471.71 (6,457.80) [a]	2,561.71 (478.35)
Labor (000' people)	8,025.24 (424.57)	6,686.76 (273.98)
Land (000' Ha)	25,787.65 (69.73)	11,329.15 (145.03)
Livestock (000' TLU)	105,006.62 (2,967.30)	45,667.26 (1,106.64)
Capital (Tractor numbers)	8913.9 (2390.82)	3441.70 (1281.79)
Output (Means)		
Agricultural PIN (1999 international dollars)	69.61 (21.25)	75.4 (13.68)

Source: Own computations based on FAOSTAT (2006).
[a] Values in parentheses are standard deviations of means.

was:

$$p^*_{it} = z'_{it}\beta + y'_{it}\alpha + e_{it} \quad i = 1,........,N.; and t = 1,........T. \quad (6$$

where p was the change in productivity index (either progress for p> 1; or regress for p< 1), z'_{it} represented a (1×J) vector of explanatory agricultural science and technology policy systems' institutional variables posited to induce productivity change in the agricultural sector; y'_{it} was a (1×k) vector of explanatory government programs that support functioning of AS&T institutions; β and α were vectors of parameters to be estimated, and $e_{it} \approx N(0,\sigma^2)$. A logistic regression was considered suitable because of its ability to delineate the institutions that enhanced the probability of realizing efficiency and technical progress in Kenyan and Ugandan agriculture. A similar approach has been utilized by Worthington (2000) in evaluating efficiency and technical change determinants in Australian building societies.

Data

DEA Input-output Data

Technical efficiency was derived using FAO input and output data for the years 1969 to 2002 (FAOSTAT, 2006). Output was net production at 1999-2001 international dollars derived using a Geary-Khamis formula for the agricultural sector (PIN) (Rao *et al.,* 2004). Inputs were agricultural land, agricultural labour, capital, fertilizer and livestock. Agricultural land referred to the share of land area that is arable, under permanent crops, and under permanent pastures. Labour comprised the number of people economically active or searching for employment in agriculture. Fertilizer included the nutrient equivalent of nitrogen, potash and phosphates in tonnes as consumed by a country. Livestock was the aggregate total livestock units (TLU) derived as a weighted sum of different livestock species -camels, cattle, pigs, sheep, and goats- as suggested by ILCA (1990). Capital was a simple aggregate number of tractors in use at national level with no quality adjustment. These inputs and outputs are summarised in Table 2.

AS and T Policy System's Institutional Changes

A review of the changes in the Kenyan and Ugandan AS and T policy environment and the accompanying institutional arrangements was undertaken. The policy instruments guiding the institutional arrangements within the four system components are summarized in Table 3. These institutional shifts were included in the logistic regression as dummy variables. Due to the time lag associated with realizing gains from investment in basic education, this dummy was omitted from the regression analysis.

Table 3. Institutional arrangements within the AS&T policy system in Kenya and Uganda – 1963 to 2005.

AS and T policy system institutional arrangement	Institution status	Years	
		Kenya	Uganda
Economic openness for technology and capital exchange	Largely closed with controlled foreign exchange regime	1963-1995	1963-1990
	Largely open economy with liberalized foreign exchange regime	1996-2005	1991-2005
Agricultural research regulatory system	Public research fragmented into different departments in government	1963-1979	1963-1990
	Public research defined and regulated through legislation	1980-2005	1991-2005
Patent protection regulatory system	Limited protection for intellectual property rights	1963-1998	1963-1993
	Protection of property rights provided for through legislation	1999-2005	1994-2005
Agricultural extension regulatory system	Largely pubic driven extension services	1963-1997	1963-1997
	Decentralized extension	1998-2005	1998-2005
Level of regulation/accessibility of the education system	Cost-sharing basic education/non-universal free basic education	1963-2002	1962-1996
	Universal free basic education	2003-2005	1997-2005

Source: Authors compilation.

Government Programs Supporting Functioning of AS and T Policy System's Institutional Innovations

Other variables that were considered to influence technical and efficiency change, by augmenting the functioning of the prevailing institutions were also included. These were:

(i) Literacy level (LITERACY): Literacy among population over 15 years was used as the indicator of labour quality, being an outcome of level of access to education. Data were obtained from the World Bank (2006) online database, supplemented by review of records from the Uganda and the Kenya Bureau of Statistics.

(ii) Road density (ROAD): This was measured as the total length of paved road per square km of agricultural land and acted as a proxy for the transaction costs that may be incurred in accessing technologies. Data on the length of paved road were obtained from the Uganda and Kenya Bureau of Statistics and from the World Bank online database.

(iii) Telephone connection per 1,000 economically active population (PHONE): This comprised total fixed telephone and mobile lines per 1000 people of the population and was used as a proxy for transaction costs in accessing agricultural information. Household with access to telephone services have been shown to be more likely to access extension services than those without (Mugunieri and Omiti, 2007). Data was obtained from statistical abstracts and the World Bank online database.

(iv) Irrigation investment (IRRIGATE): This was computed as the ratio of net irrigated area to net-cropped area. It captured the influence of irrigation on productivity above and beyond its value as an input (Rosegrant and Evenson, 1995). Data used were obtained from Faostat.

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

(v) Life expectancy (LIFE): The number of years a newborn would live if prevailing patterns of mortality at birth were to stay the same throughout his/her life was included as an indicator of quality of agricultural labour, as suggested by Fulginiti and Perrin (1998). Data was obtained from the Uganda Bureau of Statistics, the Kenya Bureau of Statistics, and the World Bank online database.

(vi) Rainfall (RAIN): Rain is an important determinant of agricultural production. Rainfall data were obtained from the International Food Policy Research Institute database, where a single rainfall entry was derived to represent rainfall-level for the whole country.

Two logistic models were estimated, with the dependent variables being the efficiency change (progress or regress), and technical change (progress or regress). The independent variables are given in Table 4.

RESULTS AND DISCUSSIONS

Trends in Efficiency and Technical Change in Kenya and Uganda

Overall, the proportion of years in which technical efficiency progress was recorded was 53%, being lower in Uganda (52%) than Kenya (55%). This difference was not statistically significant (χ^2= 0.06; P> 0.800). On the other hand, technical change progress was experienced in 56% of the years, being higher in Kenya (61%) than Uganda (52%). The differences were also not significantly different (χ^2= 0.224; P> 0.600). The mean technical efficiency change index was higher for Uganda (1.0103; std. dev. 0.096) than for Kenya (1.0054; std. dev. 0.0676). The same applied to the technical change estimates, being higher for Uganda (1.0082; std dev. 0.0417) than for Kenya (1.0024; std dev. 0.0482). These scores were, however, not

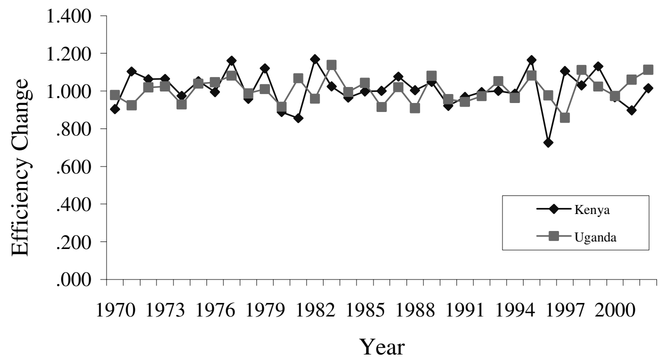

Figure 1. Trends in efficiency change estimates in Kenya and Uganda between 1970 and 2002.

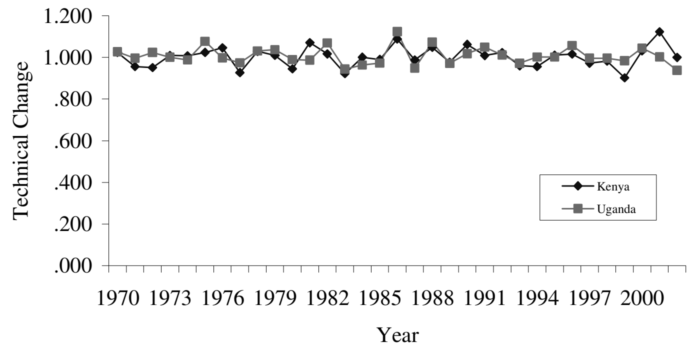

Figure 2. Trends in technical change estimates in Kenya and Uganda between 1970 and 2002.

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

Table 4. Description of variables hypothesized to influence progress/regress in technical and efficiency change.

Variable	Description	Means		
		Kenya	Uganda	Polled
ECO_OPEN	Economic openness: dummy variable (1; 0). 1= Liberalized trade regime 0= Controlled/Protected trade regime	0.30 (0.47)[a]	0.30 (0.47)	0.30 (0.46)
AG_RES	Agricultural research regulatory system: dummy variable (1; 0) 1= Research undertaken by specific agencies (Thematic research) 0= Implementation fragmented	0.70 (0.47)	0.36 (0.49)	0.53 (0.50)
IPR	Intellectual property rights regulatory system: dummy variable (1; 0) 1= Intellectual property rights laws enacted and made operational 0= No clear intellectual property rights laws operationalised	0.12 (0.33)	0.27 (0.45)	0.20 (0.40)
AG_EXTEN	Agricultural extension regulatory system: dummy variable (1; 0) 1= Decentralized R and D regime 0= Centralized R and D	0.15 (0.36)	0.15 (0.36)	0.15 (0.36)
Rain	Mean annual rainfall in mm	784.58 (146.91)	1228.96 (89.87)	1006.77 (254.53)
Literate	Adult literacy level (%)	64.14 (13.53)	52.50 (11.00)	58.32 (13.57)
Irrigate	Irrigated land over total arable land (%)	0.21 (0.067)	0.064 (0.015)	0.135 (0.087)
Road	Paved road length in km per 10000 Ha agricultural land	2.57 (0.75)	1.89 (0.84)	2.23 (0.86)
Life	Quality of the agricultural labour force: Life expectancy at birth (Years)	54.23 (3.29)	47.79 (3.27)	51.01 (4.60)
Phone	Telephone connections per 1000 head	21.78 (22.17)	7.32 (9.65)	14.55 (18.46)
COUNTRY	Dummy for country of study: 1= Kenya; 0= Uganda	-	-	-

Source: Own estimates.
[a] Figures in parentheses are standard deviations.

significantly different. These results are summarised in Figures 1 and 2.

A Chow test was undertaken to test for existence of a structural break in data across the two study countries (Chow, 1960). The DEA generated technical efficiency estimates were used as the dependent variable, with the country dummy as the group variable and all the continuous variables in Table 4 as the predictors. The test indicated that the set of regression parameters did not differ significantly across the countries (χ^2= 0.0441; P> 0.646). This provided a basis for estimating a pooled model for the two countries.

Impact of AS and T Policies on Efficiency and Technical Change

Table 5 presents the results of the specific institutional settings that enhanced the

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

Table 5. Logit estimates of probability of having technical change progress in Kenyan and Ugandan agriculture (Dependent variable: Technical change progress).

Variable	Parameter estimate (β)	Standard error	Exp(β)
ECO_OPEN (1)	6.383***	2.491	591.555
Country (1)	-2.882	2.609	0.1786
AG_RES (1)	3.012*	2.131	20.331
IPR (1)	-3.040*	2.063	0.048
AG_EXTEN (1)	4.840***	2.026	126.520
Rain	-0.002	0.003	0.998
Literate	1.196**	0.108	8.822
Irrigate	34.099**	19.344	7.54e+14
Road	5.602***	2.449	270.998
Life	-0.383*	0.235	0.682
Phone	0.074	0.205	1.077
Constant	7.001	10.703	1097.576

N= 66
Model χ^2 = 13.815; df= 10, P< 0.182;
-2 Log likelihood= 69.646
Hosmer and Lemeshow χ^2 = 7.140; df= 8; P< 0.522

*** P< 1%, ** P< 5%, * P< 10%.

probability of experiencing efficiency change progress in Kenyan and Ugandan Agriculture. The results demonstrate the intuitive responsiveness of the success of the agricultural sectors of the study countries to realizing technical progress according to six factors: economic liberalization (ECO_OPEN), decentralization of research and extension (AG_EXTEN), introduction of an institutionalized agricultural research framework (AG_RES), improved literacy (LITERATE), enhanced road network (ROAD) and investments in the irrigation system (IRRIGATE). Factors that had a negative influence included introduction of a regulatory system for intellectual property rights (PATENT) and improvement in life expectancy (LIFE). The Hosmer and Lemeshow Goodness-of-fit test statistic was 7.140 (P< 0.522) implying that the model's estimates fitted the data well, and that it explained much of the variance in the dependent variable.

On the other hand, technical efficiency change was positively influenced by the reorganization of the regulatory framework of the intellectual property rights system (PATENT), investments in irrigation (IRRIGATE), enhanced road network (ROAD) and a higher level of precipitation (RAIN) as seen in Table 6. However, the economic liberalization process (ECO_OPEN) and the decentralization of research and extension services (AG_EXTEN) had the immediate effect of causing a negative efficiency change. The same applied to country specific variables like the quality of the production resources. The estimated parameters for improved literacy levels (LITERATE) and enhanced life expectancy at birth (LIFE) had a positive sign but their impact on the probability of effecting technical efficiency change was insignificant.

Economic Openness–transboundary Technology Transfer

Rao *et al.* (2004) have noted that open economies are more likely to adopt new technologies from abroad. They also argue that economic openness is an indicator of diminished distortions within the product and factor markets. A wide-open economy is expected to have efficient labour and commodity markets leading to more efficient allocation of resources and positive efficiency and technical change. This study has, however, shown that holding the other

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

Table 6. Logit estimates of probability of having positive technical efficiency change in Kenyan and Ugandan agriculture (Dependent variable: Efficiency change progress).

Variable	Parameter estimate (β)	Standard error	Exp(β)
ECO_OPEN (1)	-4.551**	2.154	0.011
COUNTRY (1)	-5.175**	2.777	0.006
AG_RES (1)	-1.244	2.002	0.288
IPR (1)	2.255*	1.852	9.531
AG_EXTEN (1)	-4.002**	1.885	0.018
Rain	0.005*	0.003	1.005
Literate	0.105	0.104	1.110
Irrigate	28.845*	18.502	152.009
Road	3.441*	2.254	14.263
Life	0.244	0.228	1.276
Phone	0.018	0.202	1.002
Constant	3.499	10.513	20.030
N= 66			

Model χ^2= 12.426; df= 10, P< 0.258;
-2 Log likelihood= 70.485
Hosmer and Lemeshow χ^2= 5.522; df= 8; P< 0.701

determinants constant, the agricultural sector under a liberalized economic regime was more likely to realize positive technical change, but not efficiency change in the short term. The odds that these economies would realize technical progress in an open economic policy regime was 592 times the odds that they would be in a protected economy, implying that by opening up their economies, Kenya and Uganda created an environment that enabled more robust technology transfer from foreign countries. However, the opening up of the trade regime had a negative effect on efficiency change. This can partly be explained by producer's loss of benefits that accrued from policies that distorted agricultural factor and product markets in Kenya and Uganda (Collier and Reinikka, 2001). Under the controlled trade regime, there were three categories of such policies that protected producers. The first group included policies that restricted access of imports into domestic markets. This was achieved through the use of instruments like tariffs, non-tariff barriers and quotas. Second, there existed domestic support policies, that included various forms of assistance to domestic producers such as production subsidies and price support which raised the prices of agricultural products while reducing those of inputs. Third, there were direct export subsidies (export compensation). By removing these support schemes, producers appears have been exposed to shocks that affected the overall efficiency gains within the agricultural sector.

Decentralization of Extension Services

The odds that the agricultural sectors in Kenya and Uganda would experience technical progress in a decentralized agricultural extension regime were 127 times greater than in a centralized extension regime. These findings confirm the widely accepted notion that decentralization of extension services predisposes the agricultural sectors of developing nations to increased technology acquisition (Wanga, 1999). In the context of these two countries, decentralization has been conceptualized as involving the dynamics of reorganizing government service delivery and by transferring responsibilities to decentralised (governmental or non-governmental) and private organisations with the objective of improving relevance and responsiveness to users (Mugunieri and Omiti, 2007). The

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

embrace of decentralization by most developing countries emanated from the realization that centralized systems had been associated with poor governance and a lack of institutional innovations that would spur greater efficiency and accountability in the mobilization, organization and control of resources (Amudavi, 2003).

Just like economic liberalization, decentralization of agricultural extension services appears to have had the immediate effect of causing a regress in technical efficiency gain. A critical look at the decentralization process in Kenya and Uganda reveals some salient underlying features. This process appears to have been relatively successful for major crops where the responsibility of farmer education and dissemination of agricultural information was transferred to various development authorities, boards, cooperatives and factories. This transfer of responsibilities contributed to farmer participation in the running and management of extension programmes and in meeting the cost of the extension services, implying that these services were successfully decentralized and privatized (Mugunieri and Omiti, 2007). In contrast, the low-value or traditional food crops sectors which form a significant part of the agricultural sectors in both countries benefited much less, if at all, from decentralization. Livestock production within the pastoral and agropastoral areas was another relatively neglected, but significant sector. There appears to be an apparent lack of inertia to harness the potential of this sub-sector through proper management and education. Last but not least for Kenya, there is the smallholder dairy sub-sector that contributes 60–80% of Kenya's milk output and owns about 83% of its dairy cattle (Peeler and Omore, 1997). Previously reliant on the public sector for extension support, the extension infrastructure these farmers are faced with following the collapse of government support is not well understood. These three important sub-sectors seem not to have benefited from decentralization, and this has probably led to an overall decline in efficiency gain.

Intellectual Property Rights (IPR)

This study has shown that the reorganization of the intellectual property rights regulation system had a significant but negative influence on technical change but positive impact on efficiency change in Kenya's and Uganda's agricultural sectors. The impact on technical change is contrary to the argument put forward while instituting intellectual property rights in a country, namely that they are likely to spur technological growth, encourage innovation, promote trade and contribute to overall development in a country (Siyoko *et al.,* 2006). The intellectual property rights regulatory system in Kenya and Uganda comprises copyright laws, trademarks, patent, and seed and plant varieties protection laws. With the exception of the copyright laws, all other laws are expected to affect agricultural productivity through their influence on product and factor markets. This system of regulations is expected to create incentives to invent and to apply knowledge in production. However, the important policy question, particularly for developing countries, is whether this system of laws may work as a tool for enhancing technological innovation, in the same way they do in developed countries due to lack of supportive infrastructure.

In both countries, the staffing of intellectual property management and implementing organizations is a major challenge and, as such, they experience resource constraints in terms of trained personnel to manage the volume and complexity of work envisaged under the new IPR regulatory regime. It is a major challenge for organizations to attract and maintain a multi-disciplinary work force with a good grasp of intellectual property issues and how they relate to developmental goals. Another shortcoming is that, historically, scientists who have limited understanding of the law have continued to man these organizations. Staff within these organizations require training to bring them up to date with the latest concepts, issues and technologies in intellectual property regulation and administration, current practices and interpretation of intellectual property laws in line with evolving international regimes and ensuing national obligations. In addition, the training of enforcement officers such as police inspectors, customs and revenue officers is critical for the effective implementation of the IPR laws. These constraints may have impeded realization of the desired benefits from an IPR regulatory system and, by extension, the movement of the frontier.

One way in which Kenya and Uganda can fast-track benefits from IPR is by taking a pro-active role in fostering close working relationships with regional and international organizations. As a starting point, the East African region boasts regional and international organizations whose mandates vary but do have IPR implications. Examples include the Consultative Group on International Agricultural Research (CGIAR), comprising the International Plant Genetic Resources Institute (IPGRI), International Livestock Research Institute (ILRI) for research on livestock and the World Agroforestry Centre (ICRAF) for agro-forestry. These organizations have, both individually and collectively under the CGIAR, formulated intellectual property policies to guide their investment in research. The main thrust of these policies is developing public goods and putting all intellectual property generated in the public domain, building the capacity of partners e.g., the Genetic Resources Policy Initiative (GRPI) established by IPGRI to strengthen the capacity of national policy makers in southern countries to develop comprehensive genetic resources policy frameworks. Other fora from which intellectual property capacity can be sourced include the United Nations Food and Agriculture Organization (FAO) that is supporting some initiatives in the region with regard to reviewing local phytosanitary laws in order to bring them to conformity with the International Plant Protection Convention (IPPC) and the revision of the Seeds and Plant Varieties Acts.

It is generally accepted that a comprehensive system of law which protects intellectual property rights by providing creators of ideas a safe and conducive atmosphere in which to develop those ideas, is a prerequisite for technological growth. While it is essential to adopt legal and policy measures in regard to IPRs in order to effectively address the existing challenges and emergent problems, Kenya and Uganda need to budget for adequate resources for implementing and training institutions to carry out the relevant administrative and capacity enhancing activities.

Impact of Other Policies

Interventions aimed at enhancing access to education were envisaged to play a pivotal role in enhancing technical and efficiency change in the agricultural sector of both Kenya and Uganda. Only the universal free basic education that was effected in Uganda in 1997 and in Kenya in 2002 was identified as having achieved the goal of increasing access to education. However, due to the expected lag effect of this policy in enhancing the literacy level of the adult population, it was not included in the logistic model. Instead, the literacy level of the adult population was used as an indicator of the outcome of policies that were aimed at improving the education access within the agricultural labour force. The significance of the literacy level depends on whether the technologies in use are complex and knowledge intensive. If the technologies are complex, they may place demans on farmers since they require more information and skills for their successful adoption (Craig *et al.,* 1997). These arguments are in tandem with findings of this study where increased literacy significantly influenced technical

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

progress in contrast to advancement in age that had a significant negative effect, perhaps an indicator of laxity in embracing new technologies as one gets older. Both enhanced literacy and age had a positive influence on efficiency change but without reaching desirable levels of significance. This implies that improved literacy increases the propensity to acquire new production practices, but does not significantly contribute to the improved efficiency in utilization of the resources acquired over time. On the other hand, investment in irrigation significantly contributed to positive changes in both technical and efficiency change, with the effect on technological change being more pronounced. The fact that irrigation provides assurance for water accessibility and increases a producer's proclivity for investments in new technologies.

The consolidation of agricultural research into distinct research organizations led to progress in technical change but had an insignificant effect on efficiency change. Following independence from the British in 1962 and 1963 for Kenya and Uganda, respectively, regional research agencies were transferred with minimum disruption to the newly established governments. Research continued to be implemented under these regional research organizations until 1977 when the East African community collapsed. The respective governments reorganized all agricultural R and D into a number of semi-autonomous organizations through reforms implemented under the National Councils for Science and Technology that were established in Kenya in 1977 and Uganda in 1992. Following inception of these institutions, they have continued to undergo continuous transformation to enhance their efficiency and improve their research results and outreach capabilities, which have partly contributed to their contribution to improvements in technical change. However, the linkages between these organizations and farmers have been minimal (Mugunieri and Omiti, 2007), leading to limited farmer application of their outputs and, consequent, an insignificant relationship with efficiency change.

Results of this study show significant country level effects on technical efficiency change, but not technical change. Omamo *et al.* (2005) suggested a framework for categorizing AS and T policy systems in developing countries that is founded on the stages (or "generations") of development of the policy systems. The systems are categorized as first, second or third generation. Kenya is categorized as second generation whereas Uganda is first. The capacity of countries to innovate and commercialize new technologies is likely to reduce from third to first generation policy systems. This may be due to differences in investments in some of the policy system components (like research, extension and education). However, countries at a lower level of policy system development can transcend such country level constraints and realize performances associated with higher level policy systems through the harnessing of other system components (like transboundary technology acquisition) (Avila and Evenson, 2005). This might explain why country level effects did not significantly influence technical change between Kenya and Uganda. However, the fact that these effects significantly influenced technical efficiency change is not surprising, and may find an explanation in the concept of convergence of technical efficiency. This concept stipulates that the change in technical efficiency level is an indicator of catching up or convergence to the best-practice production frontier where the expectation is that, in market based economies, the economic efficiency of less productive economies would grow faster than that of more productive countries (Rao and Coelli, 1998).

CONCLUSIONS

This paper presents the findings of a study that evaluated conditions and changes in the institutional arrangements within the AS&T policy system, with the aim of identifying the institutions that encompassed innovations that promoted productivity growth in Kenya and Uganda between 1970 and 2002. An annual growth in technical change was 0.8% and 0.3% in Uganda and Kenya, respectively; these figures are within the range of the African average derived by Rao and Coelli (1998) of 0.7%. The growth in efficiency change was 1.03% for Uganda and 0.82% for Kenya. Factors that were established to be influencing technical progress positively included: economic liberalization, decentralization of research and extension, introduction of thematic agricultural research, improved literacy, an enhanced road network and investments in the irrigation system. Introduction of a regulatory system for intellectual property rights and an improvement in life expectancy had a negative influence on technical progress. On the other hand, efficiency change was positively influenced by the enactment of a regulatory framework for the intellectual property rights system, investments in irrigation, an enhanced road network and a higher level of precipitation. However, the economic liberalization process and the decentralization of research and extension services had the immediate effect of causing a negative efficiency change. However, care should be taken when interpreting these results as they involved estimation of productivity using conventional agricultural inputs without taking into account quality adjustments, an aspect that can be incorporated in future studies addressing this area.

REFERENCES

1. Alston, J. M., Pardey, P. G. and Taylor, M. J. 2001. *Agricultural Science Policy: Changing Global Agendas.* IFPRI/Johns Hopkins University Press, Washington, DC.
2. Alston, J. M., Norton, G. W. and Pardey, P. G. 1995. *Science under Scarcity: Principals and Practice of Agricultural Research Evaluation and Priority Setting*. Cornell University Press, Ithaca. (Reprinted in Soft Cover by CAB International 1998).
3. Amudavi, D. M. 2003. Advancing a Partnership Model of Extension to Support the Kenya National Agriculture and Livestock Extension Program (NALEP) in Rural Livelihood Improvement. *Proceedings of the 19th Annual Conference,* AIAEE 2003, Raleigh, North Carolina, USA. PP. 43 - 57.
4. Avila, A. F. D. and Evenson, R. E. 2005. Total Factor Productivity Growth in Agriculture: The Role of Technological Capital: Research Report. Economic Growth Centre, Yale University, New Haven.
5. Caves, D. W., Christensen, L. R. and Diewert, W. E. 1982. The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. *Econometrica*, **50**: 1393-1414.
6. Chow, G. C. 1960. Tests of Equality between Sets of Coefficients in Two Linear Regressions. *Econometrica*, **28(3):** 591-605.
7. Coelli, T. 1996. *A Guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program*. Centre for Efficiency and Productivity Analysis (CEPA), Working Paper 96/08. University of New England.
8. Collier, P. and Reinikka, R. 2001. Reconstruction and Liberalization: An Overview. In: *"Uganda's Recovery–Role of Farms, Firms and Government*", Reinikka, R. and Collier, P. (Eds). The International Bank for Reconstruction and Development, Washington, DC. PP. 15-48.
9. Craig, B. J., Pardey, P. G. and Roseboom, J. 1997. International Productivity Patterns: Accounting for Input Quality, Infrastructure, and Research. *American Journal of Agricultural Economics*, **79:** 1064-1076.
10. Davis, L. and North, D. 1971. *Institutional Change and American Economic Growth*. Cambridge University Press, Cambridge, UK.
11. FAOSTAT, 2006. http://faostat.fao.org/ (Accessed December 2006)
12. Färe, R., Grosskopf, S., Lindgren, B. and Roos, P. 1992. Productivity Changes in Swedish Pharmacies 1980–1989: A Non-parametric Malmquist Approach. *Journal of Productivity Analysis*, **3**: 85 – 101.
13. Färe, R., S. Grosskopf, Norris M. and Zhang, Z. 1994. Productivity Growth, Technical Progress and Efficiency Changes in Industrialized Countries. *American Economic Review*, **84**: 66-83.

[DOR: 20.1001.1.16807073.2011.13.1.3.6]

14. Fulginiti, L. E. and Perrin, R. 1998. Agricultural Productivity in Developing Countries. *Journal of Agricultural Economics*, **19**: 45-51.
15. Hayami, Y. and Ruttan, V. W. 1970. Agricultural Productivity Differences among Countries. *American Economic Review,* **40**: 895-911.
16. ILCA (International Livestock Centre for Africa), 1990. *Livestock Systems Research Manual.* Working Paper 1. Vol. 1, International Livestock Centre for Africa, Addis Ababa Ethiopia. 287 PP.
17. Kalirajan, K. P., Obwona, M. B. and Zhao, S. 1996. A Decomposition of Total Factor Productivity Growth: The Case of Chinese Agriculture before and after Reforms. *American Journal of Agricultural Economics*, **78:** 331-338.
18. Lele, U. and S. Stone. 1989. Population Pressure, the Environment and Agricultural Intensification: Variations on the Boserup Hypothesis. The World Bank, Washington, DC.
19. Malerba, F. 1992. Learning by Firms and Incremental Technical Change. *The Economic Journal*, **102(413):** 845-859.
20. Mugunieri, G. L. and Omiti, J. M. 2007. Decentralization, Community-based Organizations and Access to Agricultural Extension Services in eastern Kenya. In: *"Decentralization and the Social Economics of Development: Lessons from Kenya*", Barrett, C. B., Mude, A. G. and Omiti, J. M. (Eds). CAB International, Wallingford. PP. 64-83.
21. Omamo, S. W., Boyd, M. and Janssen, W. 2000. Agricultural Research Policy Development. In: "London *Planning Agricultural Research: A Sourcebook*", Gijsbers, G., Janssen, W., Odame H. and Meijerink, G., (Eds.). CABI.
22. Omamo, S. W., M. Boyd, and W. Janssen. (2000). Agricultural research policy development. In *Planning agricultural research: A sourcebook,* ed. G. Gijsbers, W. Janssen, H. Hambly Odame, and G. Meijerink. London*:* CABI.
23. Omamo, S.W. and A. Naseem. (2005). Agricultural science and technology policy for growth and poverty reduction. ISNAR Discussion Paper 3. International Service for National Agricultural Research (ISNAR), IFPRI, Washington D.C.
24. Pardey, P. G., Roseboom, J. and Anderson, J. R. 1991. *Agricultural Research Policy: International Quantitative Perspectives.* International Service for National Agricultural Research (ISNAR), Cambridge University Press, Cambridge, UK. PP. xxii + 462.
25. Peeler, E. J. and Omore, A. O. 1997. *Manual of Livestock Production Systems in Kenya*. 2nd Ed., KARI/DFID National Agricultural Research Project II National Veterinary Research Centre, Kikuyu, Kenya.
26. Rao, D. S. P and Coelli, T. J. 1998. Catch-up and Convergence in Global Agricultural Productivity 1980-1995. Working Paper No. 98, Centre for Efficiency and Productivity Analysis (CEPA), Department of Econometrics, University of New England, Armidale, Australia.
27. Rao, P. D. S., Coelli, T. J. and Alauddin, M. 2004. Agricultural Productivity Growth, Employment and Poverty in Developing Countries, 1970-2000. Employment Strategy Paper 2004/9, Centre for Efficiency and Productivity Analysis (CEPA). School of Economics, University of Queensland, Australia. Also Available at http://www-ilo-mirrow.cornell.edu/public/English/employment/strat/download/esp9.pdf
28. Rosegrant, M. W. and Evenson, R. E. 1995. Total Factor Productivity and Sources of Long-term Growth in Indian Agriculture. Discussion Paper No. 7, Environment and Production Technology Division (EPTD), International Food Policy Research Institute, Washington, DC.
29. Rozelle, S. and Swinnen, J. F. M. 2003. Success and Failure of Reforms: Insights from the Transition of Agriculture. *Journal of Economics Literature*, **XLII**: 404-56.
30. Sikoyo. G. M., Nyukuri, E. and Wakhungu, J. W. 2006. Intellectual Property Protection in Africa: Status of Laws, Research and Policy Analysis in Ghana, Kenya, Nigeria, South Africa and Uganda. Ecopolicy Series No. 16, African Centre for Technology Studies, Nairobi.
31. Wanga, E. 1999. Key Note Address on New Perspectives in Rural Extension. Regional Refresher International Course in Rural Extension (ICRE) On: Challenges and Prospects, 21st Nov.-3rd Dec., 1999, Egerton University, Kenya.
32. World Bank, Food and Agriculture Organization of the United Nations, World

Health Organization, and United Nations Environment Programme, 2003. *An Assessment of Agricultural Science and Technology for Development*. Final Report of the Steering Committee for the Consultative Process on Agricultural Science and Technology. World Bank/FAO/WHO/UNEP.
33. World Bank, 2006. http://web.worldbank.org/WBSITE/EXTERNAL/ DATASTATISTICS (Accessed December 2006).
34. Worthington, A. 2000. Technical Efficiency and Technological Change in Australian Building Societies. *Abacus,* **36(2):** 180-197.

علوم کشاورزی و سیستم نهادهای سیاست تکنولوژی: تأثیر بر کارایی و بهبود فنی در کشورهای کینا و اوگاندا

گ. ل. موگونیری، س. و. امامو و گ. ا. اوبار

چکیده

نتایج ارزیابی اثر سیستمهای سازمان‌های علوم و تکنولوژی کشاورزی بر تغییرات کارایی فنی و تکنیکی در کشاروزی کشورهای کنیا و اوگاندا ارائه شده است. تحلیل پوشش داده‌ها برای برآورد تغییرات کارائی فنی و تکنیکی و مدل رگرسیون لوجسیک برای تعیین اثر سازمانهای علوم و تکنولوژی کشاورزی بکار گرفته نشد که تأثیر بهبود کارایی فنی و تکنیکی را نشان داد. افزایش کارایی تکنیکی متأثر از انتقال تکنولوژی مرزهای ملی، علوم تمرکزگرایی خدمات ترویجی، تحقیقات کشاورزی موردی و میزان تحصیلات نیروی کار کشاورزی می‌باشد. سیستم منظم حقوق معنوی (فکری) اثر منفی (کاهش) بر افزایش کارایی تکنیکی دارد. از طرف دیگر، افزایش کارایی بوسیله چارچوب منظم قانونی برای سیستم حقوق معنوی (فکری) پشتیبانی می‌شدند، لیکن تأثیر منفی بوسیله تغییرات تکنولوژی مرزی ملی و عدم تمرکز زدایی خدمات ترویجی خواهد داشت.

[DOR: 20.1001.1.16807073.2011.13.1.3.6]