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THE IMPACT OF RESEARCH AND DEVELOPMENT INVESTMENT ON AGRICULTURAL SECTOR PERFOMANCE IN KENYA

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Abstract

Purpose: The purpose of the study was to assess the impact of research and development investment/expenditure on the agricultural sector performance in Kenya.

Methodology: The study took the peoples impact assessment direction. The data for this study was collected from various government agencies such as KARI, ASTI, Kenya Agricultural Sector Data compendium website, FAOSTAT, World Bank among others. Co-integration and error correction modeling methods were used in analyzing the data for this study.

Results: Co-integration results for both the parsimonious and non-parsimonious model indicated that that there is a long-run relationship among the variables in the agriculture performance in Kenya. Further, findings in this study indicated that the variables under study were insignificant determinants of the long run Total Factor Productivity of the agricultural sector. Meanwhile, Trade openness was the only significant determinant of the short run agricultural Total Factor Productivity.

Unique Contribution to Policy and Practice: This study recommends the institutionalization of policies aimed at ensuring interaction between the various stakeholders in the agricultural sectors. This interaction will ensure that resources are better allocated to reduce duplication of research and dissemination activities. In addition, greater collaboration among the stakeholders will promote and strengthen the connection between research, policy and the application of research findings. The study further advocates that the government should follow a trade liberazation oriented approach to the agricultural sector as opposed to a trade tightening approach.

Keywords: *Total R&D investment, long run determinants, short runs determinants, agricultural sector and performance.*

1.0 INTRODUCTION

Agriculture in Kenya continues to dominate Kenya's economy, although only 15-17 percent of Kenya's total land area has sufficient fertility and rainfall to be farmed and only 7-8 percent can be classified as first-class land, that is, land which can support rain fed agricultural production year in year out. In 2006, almost 75 percent of working Kenyans made their living by farming, compared with 80 percent in 1980. About one-half of Kenya's total agricultural output is non-marketed subsistence production. Agriculture is also the largest contributor to Kenya's gross domestic product (GDP). In 2005, agriculture, including forestry and fishing, accounted for about 24 percent of the GDP, as well as for 18 percent of wage employment and 50 percent of revenue from exports (Mwanda, 2008). Other reports, for instance, Kirwa (2006) assert that agriculture accounts for about 26% of the GDP directly, while the indirect contribution to GDP stands at 27%.

Nevertheless, the proportion of Kenya's economy that relies on agriculture is relatively small compared to its East African Community neighbours. In Uganda, agriculture accounts for 42 percent of GDP. Rural families rely on food crops for their chief source of income (Mwanda, 2008). In Tanzania, agriculture accounts for 50 percent of GDP, 85 percent of exports and employs 90 percent of the workforce.

Despite policy and structural problems, the agricultural sector in Kenya has been among the most dynamic and well diversified in Sub-Saharan Africa. Between 1960 and 1970 the sector grew at 4.7 per cent per annum, faster than the rate of population growth. During this time, agriculture, on average, accounted for a quarter to a third of GDP depending upon the impact of weather conditions and trend in the terms of trade, and the performance of other sectors. It was during this first decade after Independence that Kenya enjoyed rapid economic growth mainly predicated on the performance of the agricultural sector. However, between 1970 and 1982, the sector growth rate declined to only 2.7 per cent as the actual production per capita fell to 1.2 per cent per annum (SRA,2004); and the sector fared badly and its share declined closer to a quarter of the country's GDP. During the 1980s, the sector growth rate showed gradual improvement, from 3.4 per cent per annum between 1980 and 1984, to 4.3 per cent between 1985 and 1988. Although the sector showed impressive improvement in its growth rate during the second half of the 1980s – due principally to the expansion in the area cultivated by the smallholders, policy and structural constraints continued to impact negatively on the agricultural production. (African Development Bank, 2001).

Statistics from World Bank report (2010) indicate that agricultural sector grew slowly during the 1980s and early 1990s but has regained momentum since about 1993, despite periodic shocks. Growth in agriculture was constrained between 1986 and 1993 as the economy was liberalized and structural reforms implemented. During this period, the reforms were introduced in a piecemeal manner, poorly sequenced, and experienced many reversals. According to the graph below, agricultural sector, growth has fluctuated up and down since 1993 and only showed a consistent positive outlook only after the 2002 elections. The agricultural sector grew by 4.1% in the period 2002-2006.Overall, statistics from World Bank indicate that agricultural sector growth has averaged 2.4% from the year 1982 to the year 2006.

The agricultural sector in Kenya is composed of smallholder farms, large mixed farms, plantations (or estates), ranches and pastoralists (mainly in the arid and semi-arid regions). The smallholder sector, accounting for over 95 percent of holdings (using a threshold of 12.5 hectares), is the most dominant. About 8.6 million hectares (i.e. less than 20 percent) of land is considered to be of high or medium potential. Of this, about 2.8 million hectares are under crop production, 2.4 million hectares are under dairy farms, and the remaining 3.4 million hectares under extensive grazing and national parks.

According to World Bank Report (2010), some agricultural subsectors have performed well, providing an opportunity to draw positive lessons. Examples include tea, export horticulture (mostly cut flowers but also vegetables), and dairy. The poor performers are coffee (which declined dramatically between 1995 and 2003) and meat. The only major subsector that has stagnated is maize, despite considerable government efforts to sustain it with price supports, research, and extension.

The tea sub sector is a dominant sub sector followed by the coffee sub sector. The horticultural sub sector has seen unprecedented growth from 1995 to date as more companies venture into production and export of flowers and fresh produce. The sugar industry has faced significant challenges and it is the government’s intention to improve the sector. This industry is expected to show good growth over the next few years, should the government implement their stated policies on having quotas on the importation of sugar, improvement in the competitiveness and the consequent privatization of government owned sugar mills, and the subsidies aimed at reducing the current debt levels of farmers. Other sectors where the country has significant untapped resources include cotton, forestry, fishing, pyrethrum, and macadamia nuts (PWC report, 2009).

The strengthening of the agricultural sector is a prerequisite condition for achieving economic recovery and growth. A number of guiding policies and strategies have greatly influenced the sector. These include the Fourth and Fifth Development plans, Economic Recovery Strategy (ERS), the Strategy for Revitalizing Agriculture (SRA) and now the Vision 2030.

Public agricultural spending in Kenya, however, has been falling dramatically in real terms, having peaked in the late 1980s and declining steadily through the 1990s. In inflation-adjusted terms, public spending on agriculture in the late 1990s was about half of the amounts spent in the late 1980s. Government projections indicate that agricultural spending will gradually increase as a percentage of the national budget over the next five years but will remain at around 5 percent. (World Bank Report, 2010).

Overall, agricultural sector budget in comparison with the national budget has equally declined to about 4.3 percent in 2008/09 and could fall further to 2.8 percent in 2009/10. Meanwhile, deeper analysis of the sector’s total expenditures reveals that resource absorption capacity has been commendable averaging over 90 percent during the review period. The highest absorption rate of 98 percent was recorded in 2008/09.

Worries about food security and climate change have led to increased funding of agricultural research from a number of major donors, including DFID, World Bank and the Bill and Melinda Gates Foundation (Hall & Dijkman, 2009). DFID has announced a doubling of spending on agricultural research, while other bodies such as the World Bank and the Bill and Melinda Gates

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Foundation have also increased their spending on agriculture. However, researchers such as Hall and Dijkman (2009) question whether this research funding is enough to make a difference in farmers' fields, and argues that research should be seen as an integrated part of a more broadly conceived capacity for change.

1.1 The Research Problem

Food security has been an important concern for the Kenyan government. In order to achieve this, the agriculture sector has been pinpointed by various sessional papers as the sector that can make food security possible. For instance, the Economic Recovery Strategy (ERS) (2003-2007) identified agriculture as one of the prime sectors that would enhance food security, reduce poverty and jumpstart economic growth. The strategy for revitalizing agriculture (SRA) (2004-2014) also was put in place due to the concern for the development of agricultural sector in terms of boosting productivity and incomes, and ensuring food security, irrigation farming and enhancing diversification into non-traditional commodities. Vision 2030 also recognizes agriculture as an essential instrument and medium for the realization of economic growth. The sector is expected to contribute towards generation of wealth, employment creation, achievement of food security and significant reduction in poverty.

However, despite all these strategies, the performance of agricultural sector and in consequence the state of food security has been dismal. For instance, agriculture performance had declined seriously to -0.3% annual growth rate by the year 2002 (ASCU, 2010). In the year 2008, the local media highlighted that 10 million Kenyans were facing starvation. Since the most devastating famine in Kenya of 1984, famine has been a recurrent problem, indicating a continuing state of food insecurity. Kirwa(2006) and Ruto(2008) attributed the poor performance of agricultural sector to increased frequency of drought, inconsistencies in legal, policy and institutional framework, poor access to credit by farmers, high cost of farm inputs, declining public funding of agriculture and declining research, extension and development investment in the sector.

This study argues that most of the above problems could be addressed if there was consistency in research and development which would not only solve the infrastructural (capacity building and institutional) problems, but would also bring about policy based solutions to systemic problems such as high cost of farm inputs and poor access to credit.

Empirical studies African Development Bank, (2001); Muigai, (2005); Alila and Atieno, (2006); Odhiambo, Nyangito and Nzuma, (2004); Onjala, (2002) done on this front have had generalized conclusions. These studies identified were purely descriptive and lacked the statistical rigour associated with identifying causation between variables such as investment in R&D, on the one hand and agriculture sector performance on the other. This study therefore endeavours to bridge the research gap arising from the type of analysis (descriptive) used in previous studies.

Therefore, it is important to analyze the relationship between R&D investment and the agricultural sector performance of Kenya in an effort to draw valid policy recommendations on the economic case for investing in R&D.

Specifically, the study wishes to address the following research questions:

(i) Is there evidence of R&D led agricultural sector performance in Kenya?

(ii) What other factors affect agricultural sector performance?

1.2 Objectives

The main objective of the study is to test the R&D led agricultural performance hypothesis for Kenya. The specific objectives were:

(i) To assess the impact of total R&D investment (private , public and foreign), on agricultural sector performance

(ii) To establish the long run and short runs determinants of agricultural sector performance.

(iii) To make policy recommendations on R&D investment front, which might contribute to, accelerated agricultural sector performance.

2.0 LITERATURE REVIEW

2.1 Theoretical Literature Review

2.1.1 People Impact

Economic Impact

Economic impact measures the combined production and income effects associated with a set of R & D activities. The economic impact can be assessed through what is known as an "efficiency analysis" which compares the cost and the benefits of the project in a systematic manner (Anandajayasekeram *et al.*1996). The economic impact assessment studies range in scope and depth of evaluation from partial impact studies to comprehensive assessment of economic impacts. One popular type of partial impact assessment is adoption studies that look at the effects of new technology such as the spread of modern plant varieties on farm productivity and farmers' welfare.

Omiti *et al* (1999) describes adoption and diffusion studies undertaken in the Eastern and Central Africa region. Economic impact assessments of the more comprehensive types look beyond mere yield and crop intensities to the wider economic effects of the adoption of new technology. These studies generally estimate the economic benefits produced by research in relation to associated costs and estimate a rate of return to research investments.

Economic studies include studies that estimate economic benefits and measure economic rates of return. The literature on economic impact studies also includes a wide range of levels of impact analysis, from aggregate, national level to program and project level. The econometric approach of estimating research productivity and the total factor productivity analysis are best suited at the very aggregate-level of impact assessment. On the other hand, the economic surplus and cost-benefit studies are most suitable at the level of individual research program (Evenson, 2001). In assessing the economic impacts, research is treated as an investment and rates of return (ROR) are then estimated for this investment. ROR summarizes the benefits and costs, and income from the activity in a single number which can be easily compared with the cost of obtaining funds or rates of return obtained from alternative investments.

There are two broad approaches to estimate ROR, the econometric approach which often uses a production function (regression approach), or the total factor productivity approach to estimate the marginal rates of return (MRR). The MRR calculates the returns to the last dollar invested in each component through econometric estimation. The estimation of MRR requires good quality time series data that in most developing countries are difficult to obtain. The other approach is the surplus approach which uses a benefit - cost framework to estimate the average rate of return (ARR). The ARR takes the whole expenditure as given and calculates the rate of return to the global set of expenditures. The ARR indicates whether or not the entire investment package was successful, but not whether the allocation of resources between investment components was optimal (Oehmke *et al*., 1996)

Recently, several authors and organizations have highlighted the limitations of using economic efficiency as the principal criterion for assessing impacts. As Shaxson (1999) argues, while economic efficiency indicators may provide guidance on where to invest, they do not help in clarifying how to invest. In other words, economic assessment can help identify areas of efficient and effective research investment but has little to say on the methods for achieving research efficiency and effectiveness.

Socio-Cultural Impact

Socio-cultural impacts assessment (SIA) include the effects of research on the attitude, beliefs, resource distribution, status of women, income distribution, nutritional implications, institutional implications etc. of the community. These can be assessed through socio-economic surveys and careful monitoring. While SIA is normally undertaken within the relevant national environmental policy framework, it is not restricted to this, and SIA as a process and methodology has the potential to contribute greatly to the planning process of other types of development projects (Burdge &Vanclay, 1996).

For agricultural research, it can assist in the process of evaluation of alternatives, and to help in their understanding and management of the process of social change. However, based on a review of available studies, it is evident that SIA has rarely been applied to agricultural research programs. The estimates of social surplus in impact studies of agricultural research are based on costs and benefits that are measurable in monetary units. The social surplus methodology used in economic assessment is amenable to estimating distributional consequences of research, such as between consumers and producers, and between different income groups of consumers and producers.

Social impacts are important and need to be considered along with the economic and environmental impacts. However, conducting the economic, social and environmental impact assessment of a research program as separate disciplinary activities may be too burdensome. The challenge is to focus on some specific social, economic and environmental issues and then to explore the most appropriate methods to address them. Social Impact Assessment can enrich the impact analysis as well as provide a clearer identification of issues for research planning and prioritization.

Environmental Impact Assessment

Environmental Impact Assessment (EIA) is defined as the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made (IAIA 1998). Many countries require environmental impact assessments (EIAs) for major development projects; and, in fact, many countries have formal requirements in law and associated guidelines for carrying out EIAs. At the same time, an OECD (1994) study quoted in Omoto (2003), found that few guidelines were implemented in practice because of the lack of human and financial resources, their general, non-specific and (often) mechanistic nature, and their lack of relevance to the main tasks and problems facing guideline users. The importance of EIA is increasing in agricultural research due to the growing concerns of land degradation, deforestation and loss of biodiversity around the world. However, there are few examples of countries and research institutions that have formally assessed the environmental impacts associated with agricultural research. Environmental costs and benefits are typically not included in conventional economic impact studies discussed above. The meta-analysis of the returns to agricultural research done by Alston et al. (1998) found that out of more than 1,100 research evaluation observations, only 11 had included environmental variables in the rate of return analysis. Among other things, there is a clear lack of adequate data on which to base EIA.

Institutional Impact

Institutional impact consists of changes in organizational structures, methods of conducting scientific research, and the availability and allocation of research resources. Most of the ongoing research and development impact studies address the people level impact forgetting institutional impacts. Increasing agricultural productivity, whilst strengthening local institutions, has long been an important goal of agricultural research. Organizations play an important role in meeting this goal by improving technologies and knowledge base of the biological, social, economic and political factors that govern the performance of an agricultural system, and by strengthening local institutions' capacity and performance.

While research projects themselves are often subjected to rigorous appraisals from an economic, social and environmental perspectives, research methods and institutional aspects of a research organization tend to escape any kind of impact analysis. The impact assessment work discussed above focuses on the impact evaluation of the "technological" outputs of research organizations in the form of new techniques, methods, information and practices of agricultural systems. Institutional impact assessment involves the evaluation of the performance of a research organization in non-technological research activities such as training, networking, development of methodologies, and advisory services in the areas of research and other policies, organization and management. Assessment of the institutional impacts of such activities should therefore be an integral part of the overall impact assessment and research evaluation efforts.

There has been little methodological and practical work in the area of institutional impact assessment of agricultural research (Goldsmith 1993). This includes the impact and agricultural research organization has on capacity building, human resources development, and performance of other institutions. However, recently there has been interest to evaluate the institutional impacts. ISNAR, for example, has undertaken a major effort in this area and generated several studies and results that illustrate the conceptual and analytical methods of institutional impact assessment (Horton and Borges-Andrade 1999, Horton and Mackay 1998, Mackay et al. 1998, Mackay and Debela 1998). IFPRI has also recently undertaken several case studies to document the institutional impacts of its policy research and capacity building activities (Ryan forthcoming, Babu 2000, Paarlberg 1999). The concrete results and impacts of institutional development can be difficult to see and may take time to emerge. However, information, generated from institutional impact assessment has the great potential to lead to better, more effective actions and institutional performance of a research system.

2.2 Empirical Review

2.2.1 R&D and Agricultural Performance

The relationship between agricultural research expenditure and agricultural output/productivity is usually explored in a production function setting with specifications varying according to the nature of the data and objectives of the study [Knutson & Tweeten (1979); Norton & Davis (1981); Evenson & Pray (1991)]. As the impact of research and extension on output/productivity spans over many time periods, proper modeling of the lag relationship assumes considerable importance in the overall modeling strategy.

To circumvent the econometric problems relating to degrees of freedom and multicollinearity, researchers have used a variety of different deterministic lag formulations ranging from simple averages over time periods to more sophisticated versions such as geometric, inverted V, trapezoidal, and polynomial lags.

Measuring the social rate of return on agricultural research investment has been a standard practice accompanying agricultural research impact studies (Schultz, 1953, Griliches, 1957, Alston *et al.*, 2000). This is particularly important for developing countries where research investment is primarily a public-sector activity. Government budgets are limited and there are many competing public investment alternatives. The measured rate of return can provide guidance on funding decisions and possibly research policy implications.

It is of public interest to determine the payoffs to society from past investment on public agricultural research in assessing whether additional investment is likely to be worthwhile. A standard methodology for estimation of the marginal internal rate of return to R&D expenditures is widely used in the literature [Knutson and Tweeten (1979); Thirtle and Bottomley (1989); Nagy (1991); Fernandez-Cornejo and Shumway (1997) and Evenson, Pray and Rosegrant (1999)].

The estimation of the MIRR involves the relationship in TFP and explanatory variables being estimated in double log form, with each lag coefficient on the R&D variable representing the productivity elasticity of R&D for that year.

Davis (1980) estimated an aggregate output Cobb-Douglas production function model for U.S. agriculture with a range of alternative lag structures and found that the conventional input coefficients as well as the research production coefficients were, by and large, the same across all specifications. The use of the simplistic lag formulations in this context saves on the data collection effort.

Pardey and Craig (1989) in their study find that while summary statistics of the lag relationship such as the mean and variance are generally not very sensitive to the choice of the lag structure, the implied rate of return to agricultural research is, however, quite sensitive to partial research production coefficients that are estimated with models with inappropriate lag structures. To fully account for the effect of research on output/productivity, the study indicated the need for long lags of at least thirty years.

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Fernandez-Cornejo and Shumway (1997) have examined the agricultural research productivity relationship for Mexican agriculture for the period 1940-90. First, a Tornqvist-Theil (T-T) Total Factor Productivity (TFP) index is calculated. Then, in an application of two-stage TFP decomposition procedure, a regression model explaining TFP in terms of agricultural research spending (public research and agricultural extension) and a proxy for international transfer of technology are proposed.

Applying cointegration technique, the authors were able to determine a unique long-run relationship between TFP, agricultural research investment, and U.S.agricultural productivity—used as a proxy for international transfer of technology in Mexican agriculture. Using the productivity elasticity of research from the estimated relationship, the average annual rate of return to research investment is estimated at 64 percent.

Makki, Thraen, and Tweeten (1999), explain productivity growth in U.S. agriculture sector in terms of time-series data on public and private research investments, farmers' education, terms of trade, government commodity programmes, and weather. A significant cointegration relationship is found between research investment and agricultural productivity. Based on the estimated coefficients on the lags of public and private research variables, the authors estimate the internal rate of return of 27 percent for the public R&E and 6 percent for private R&D.

In the context of Pakistan, Khan and Akbari (1986) estimated a relationship between agricultural output and agricultural research and extension in a production function setting with a 10-year lag structure and found the rate of return to agricultural research to be 32 percent. Nagy (1991) estimated a productivity decomposition model for the period 1959-60 to 1978-79, in which TFP is functionally related to current weather conditions, current education level of farmers and the impact of research and extension. In an ordinary least squares estimation, eight, ten and twelve year lags for the research expenditure and extension variable were tried and Nagy found the ten-year lag to be statistically superior to the other two lag specifications. Utilizing the estimated coefficients of research and extension, the marginal internal rate of return to agricultural research and extension in Pakistan was calculated to be 64.5 percent.

Rosegrant and Evenson (1993), in their study of TFP for Pakistan's crop sector, found research variables, share of modern varieties, literacy and overall share of irrigation to have the greatest impact on productivity growth. Their estimate of the marginal rate of return to crop-specific research is 58 percent, general research 39 percent, and that specific to HYVs 51 percent.

The model of the long-run determinants of TFP is based on the production function framework in which TFP growth is identified as a shift in the production function representing technical change. It is measured as that part of output growth not explained by growth of measured factor inputs (Solow, 1957, Jorgenson and Griliches, 1967, Jorgenson, 1995), Measured TFP growth therefore includes not only pure technical change, but also factors and measurement errors left unaccounted for by measurable conventional inputs (Ruttan, 1987, Alston et al., 1998b, APO, 2001, Oguchi, 2004). It thus includes, but is not confined to, the effects of advances of knowledge or technological progress (Denison, 1967, Griliches, 1996).

Local studies such as Odhiambo,Nyangito and Nzuma (2004) had mixed results in the study on sources and determinants of agricultural sector performance. Onjala (2002) also had unexpected

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results in the study linking trade openness to total factor productivity in both the agricultural, manufacturing sectors and the aggregate economy.

3.0 RESEARCH METHODOLOGY

The study took the peoples impact assessment direction. The data for this study was collected from various government agencies such as KARI, ASTI, Kenya Agricultural Sector Data compendium website, FAOSTAT, World Bank among others. Co-integration and error correction modeling methods were used in analyzing the data for this study.

4.0 RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics

Table 1 shows the summary statistics of the variables used in this study. The purpose is to characterize the distributions of the variables by checking normality. The statistics indicate whether each variable is skewed to the left or skewed to the right or it is normally distributed. For the normally distributed series the expectation is that, the skewness coefficient ranges from -2 to +2.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Skewness	Min	Max
logtfpindex	26	4.738808	14.26819	4.627	-0.721	73.887
logRpu	26	6.746961	1.379728	0.339	4.802627	9.373915
logRpr	26	4.779589	1.465578	0.162	2.231089	7.697011
logRf	26	4.753595	2.128201	0.177	1.868258	8.55969
logWr	26	8.909628	0.1625872	-0.513	8.51218	9.252512
Iirr	26	0.0136538	0.0035434	0.533	0.009	0.02
TO	26	0.4890769	0.3180976	0.193	0.099	1.092
D1992	26	0.5	0.509902	0	0	1

Table 1 indicates that all variables are normally distributed with the exception of logtfpindex, which is skewed to the right.

4.2 Correlation Statistics

Findings in this study indicate that there is a weak positive but insignificant correlation between total factor productivity and public R&D expenditure, private R&D expenditure, and foreign funding. The correlation between total factor productivity and rainfall, infrastructure (irrigation), trade openness and the dummy (1992 multiparty election) was weakly negative and insignificant at 0.05 level of significance.

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Table 2: Correlation statistics

Column1	logtfp~x	logRpu	logRpr	logRf	logWr	Iirr	TO	D1992
logtfpindex	1							
logRpu	0.0571	1						
logRpr	0.0578	0.9815*	1					
logRf	0.0626	0.9214*	0.8899*	1				
logWr	-0.2834	0.0099	0.0092	0.0687	1			
Iirr	-0.169	0.6541*	0.6096*	0.7637*	0.0726	1		
TO	-0.0243	0.7217*	0.7019*	0.8373*	0.0427	0.8615*	1	
D1992	-0.0154	-0.7641*	-0.7128*	-0.8667*	-0.2	-0.8501*	-0.8667*	1

4.3 Tests for Co-Integration: The Engle-Granger Method.

The next step is to establish whether there is a long run relationship among the variables, that is, whether non-stationary variables are co-integrated. The Engle-Granger two step procedureswere used. In the first step is to generate the residuals from the long run equation of the non-stationary variables. Then stationarity of the residual was tested for using both ADF and Phillip-Peron tests. Table 3 below shows the regression results of the long run equation of the non-stationary variables.

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Table 3: Results of the long run model

Number of obs	26		Source	SS	df	MS
F(7, 18)	0.7		Model	1198.44416	7	171.26308
Prob > F	0.6035		Residual	3891.08855	18	16.171586
R-squared	0.2355		Total	5089.53271	25	203.581308
Adj R-squared	-0.0618					
Root MSE	14.703					
logtfpindex	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**[95% Conf.**	**Interval]**
logRpu	-11.6363	16.93073	-0.69	0.501	-47.20644	23.93384
logRpr	6.951474	12.04866	0.58	0.571	-18.36182	32.26476
logRf	2.018112	6.997013	0.29	0.776	-12.68207	16.71829
logWr	-14.47431	20.34161	-0.71	0.486	-57.21045	28.26182
Iirr	-78.67393	1907.555	-0.04	0.968	-4086.299	3928.951
TO	30.70249	25.63039	1.2	0.246	-23.14495	84.54993
D1992	17.56584	19.00378	0.92	0.368	-22.35962	57.49131
_cons	146.6662	200.2585	0.73	0.473	-274.0614	567.3937

In order to establish whether or not there is co-integration among the variables a test of stationarity of residuals is conducted. The ADF and P-P test statistics and critical values are shown in Tables 4.

Table 4: Co-integration Test: Two-step Engle and Granger test

Column1	Column2	1% Critical	5% Critical	10% Critical
	Test statistic	Value	Value	Value
ADF	-5.667	-3.75	-3	-2.63
P-P test	-5.531	-4.38	-3.6	-3.24

The results indicate that the residuals are stationary at 1%, 5% and 10% levels of significance using ADF and P-P test. It can then be concluded that the results suggest that there is a long-run relationship among the variables in the agriculture performance in Kenya.

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4.4 Long Run Results

Having established that the variables are stationary at different levels and that they are cointegrated, estimation results presented in Table 5 can be interpreted as long-run results. The overall goodness of fit of the model is satisfactory. The R-squared of 0.24 indicates 24 percent of the variations in log of the total factor productivity index (logtfpindex) are explained by the variables included in the model. The F-statistic measuring the joint significance of all regressors in the model is statistically insignificant at 5 per cent level. Hence, the model variables are unable to jointly explain the determinants of agricultural performance in Kenya.

The results indicate that public R&D expenditure (logRpu) has a statistically insignificant estimated coefficient at 5% level of significance (as indicated by the large p value). This implies that we reject the null hypothesis that public expenditure is a significant determinant of total factor productivity. The coefficient of logRpu (-11.64) suggests that in the long-run , an increase of one percent in the public R&D expenditure is associated with a decrease of 11.64 percent in total factor productivity. Conversely, a drop in public R&D investment would be associated with an increase in total factor productivity.

Foreign funding (logRf) has a statistically insignificant regression coefficient at 5% level of significance. Consequently, Foreign funding (logRf) is not a significant determinant of TFP as denoted by the rejection of the hypothesis at 5% level of significance. The positive sign of foreign funding (log Rf) is in line with our expectation. The coefficient of 2.02 indicates that a 1% increase in foreign funding results in a long run increase of TFP by 2.02%.

Rainfall (log Wr) had a statistically insignificant regression coefficient at a level of 5% significance. Consequently, rainfall is not a significant determinant of Total Factor Productivity. The rainfall variable has a negative coefficient (-14.47) which is surprising and out of line with our expectation. The implication is that increases in rainfall by 1% results in the long run decrease of Total Factor Productivity by 14.47%.

Infrastructure (percentage area equipped for irrigation denoted by Iirr) has a statistically insignificant coefficient at a significance level of 5%. Consequently, Infrastructure is not a significant determinant of Total Factor Productivity. The infrastructure coefficient has a negative coefficient (-78.67) which is surprising and out of line with our expectation. This result implies that an increase in the area equipped for irrigation by 1% would result in a long run decrease in Total Factor Productivity by 78.67%.

Trade openness (TO) had a statistically insignificant coefficient at 5% level of significance. Trade openness is therefore not a significant determinant of TFP. The positive sign of the coefficient (30.70) was in line with our expectation. This implies that an increase in trade openness by 1% would result in a long run increase in Total factor Productivity by 30.7%

The Dummy used to capture the 1992 multiparty election (D1992) had a statistically insignificant coefficient at 5% level of significance. The Dummy is therefore not a significant determinant of TFP. The positive sign of the coefficient (17.57) is inconsistent and out of line with the study expectation. The coefficient implies that a 1% increase in the 1992 post election effect would result in a long run increase in the TFP by 17.57%.

4.5 Short-Run Results

If variables are cointegrated, then an error-correction model can be specified to link the short-run and the long-run relationships. Residuals from the cointegrating regression are used to generate an error correction term (lagged residuals) which is then inserted into the short-run model. The estimates of the error-correction model are presented in Table 5.

Table 5: Estimation results-ECM of the Agricultural TFP in Kenya

Source	SS	df	MS	Number of obs =	25
Model	2255.13978	8	281.892472	F(8, 16) =	1.6
Residual	2811.03838	16	175.689899	Prob > F =	0.2002
Total	5066.17816	24	211.090757	R-squared =	0.4451
				Adj R-squared =	0.1677
				Root MSE =	13.255

logtfpindex	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
logWr	-27.9987	19.4082	-1.44	0.168	-69.14224	13.14484
dlogRpu	25.44039	22.18776	1.15	0.268	-21.59556	72.47635
dlogRpr	-14.49352	16.46471	-0.88	0.392	-49.39716	20.41011
dlogRf	-11.67247	6.789924	-1.72	0.105	-26.06647	2.721527
dIirr	-1828.495	1838.992	-0.99	0.335	-5726.985	2069.995
dTO	68.79868	26.61541	2.58	0.02	12.37653	125.2208
D1992	34.89387	19.18898	1.82	0.088	-5.784955	75.5727
ect	0.3546606	0.3475075	1.02	0.323	-0.3820223	1.091343
_cons	230.5763	185.5274	1.24	0.232	-162.7243	623.8769

The R-squared of 0.4451 implies that 44.51% of variations in the TFP are explained by the explanatory variables in the model. Consequently, 55.49% of the variations in the TFP could be explained by variables not included in the model. The joint F statistic, of 0.2002 is far from the

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significance level of 0.05, hence, it can be concluded that the variables in the model do not jointly explain Total Factor Productivity in the agricultural sector.

The coefficient for changes in Trade openness (TO) was the only significant coefficient at 5% level of significance. This implies that changes in Trade openness is a short run determinant of TFP. All the other variables had insignificant coefficients at 5% level of significance and this study therefore rejects the null hypothesis that changes in these variables are short run determinants of TFP.

The error correction term (ect) measures the speed of adjustment to the long run equilibrium in the dynamic model. Surprisingly, the error term is positive (0.3546) and statistically insignificant at the 5% level .This result implies that there is no gradual adjustment (convergence) to the long run equilibrium. The coefficient of 0.3546 indicates that 35% of the disequilibria in TFP achieved in one period are never corrected in the subsequent period.

4.6 A Parsimonius Model for Combined R&D Expenditure

When Public R&D, Private funding and Foreign funding were combined into one variable named Combined R&D expenditure, a more parsimonious model was established.

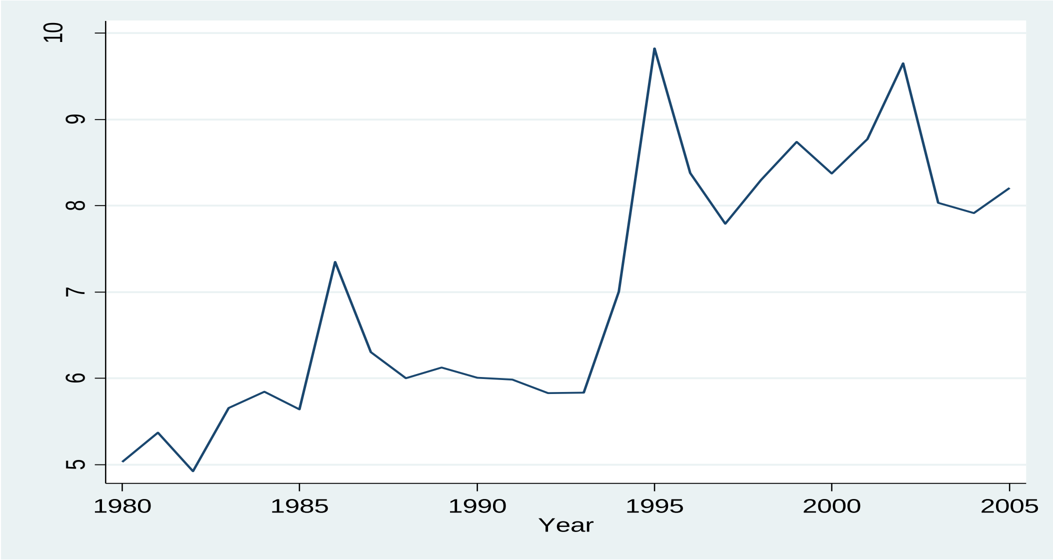
$$TFP = f\left(R^{c}, I_{irr}, TO, W_{r}, D^{1992c}\right),$$

Where;

R^{c} (+) = real total public, private and foreign funded agricultural research expenditure,

All other variables do not change and are therefore as described in the previous discussion.

Figure 1: The log of combined agricultural R&D expenditure- 1980 to 2005



4.6.1 Unit Roots Tests-Parsimonious Model

The Augmented Dick Fuller test and P Perron test for unit roots for the logRc (natural log of combined R&D expenditure) yielded t values which were not negative enough to reject the null

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hypothesis of unit roots. The variable logRc (natural log of combined R&D expenditure) is therefore non stationary.

Table 6: Unit roots tests

Column1	Column2	1% Critical	5% Critical	10% Critical
	Test statistic	Value	Value	Value
ADF	-1.83	-3.75	-3	-2.63
P-P test	-1.676	-3.75	-3	-2.63

Source: Own Computations

Further unit root tests on dlogRc (first difference of logRc) yielded test statistic values that were negative enough to reject the null hypothesis of a unit. It can therefore be said that the natural log of combined R&D expenditure is first difference stationary.

Table 7: Unit roots tests

Column1	Column2	1% Critical	5% Critical	10% Critical
	Test statistic	Value	Value	Value
ADF	-5.654	-3.75	-3	-2.63
P-P test	-5.921	-3.75	-3	-2.63

Source: Own Computations

4.6.2 Tests for Co-Integration: The Engle-Granger Method-Parsimonious Model.

In order to establish whether or not there is co-integration among the variables a test of stationarity of residuals is conducted. The ADF and P-P test statistics and critical values are shown in Tables 8. The results indicate that the residuals are stationary at 1%, 5% and 10% levels of significance using ADF and P-P test. It can then be concluded that the results suggest that there is a long-run relationship among the variables in the agriculture performance in Kenya.

Table 8: Co-integration Test: Two-step Engle and Granger test

Column1	Column2	1% Critical	5% Critical	10% Critical
	Test statistic	Value	Value	Value
ADF	-5.63	-3.75	-3	-2.63
P-P test	-5.621	-3.75	-3	-2.63

Source: Own Computations

4.6.3 Long Run Results-Parsimonious Model

Findings from the parsimonious long run model indicated that all the variables including the log of combined R&D expenditures (logRc) were insignificant determinants of agriculture TFP (logtfpindex). The results of the parsimonious model do not significantly differ from the non-parsimonious model results. It therefore follows that the researcher may be indifferent when choosing the simple structure TFP determinants model (parsimonious model) to the more complex model (non-parsimonious model) which presents R&D expenditure in its disaggregated forms i.e. Public R&D expenditure, Private R&D expenditure and Foreign Funding.

Table 9: Long run results -Parsimonious model

Source	**SS**	**df**	**MS**			**Number of obs = 26**
Model	1111.89744	5	222.379489			F(5, 20) = 1.12
Residual	3977.63526	20	198.881763			Prob > F = 0.3824
Total	5089.53271	25	203.581308			R-squared = 0.2185
						Adj R-squared = 0.0231
						Root MSE = 14.103
logtfpindex	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**[95% Conf.**	**Interval]**
logRc	-1.352807	3.555794	-0.38	0.708	-8.770064	6.06445
logWr	-14.39015	19.28172	-0.75	0.464	-54.61112	25.83081
Iirr	-516.5004	1704.453	-0.3	0.765	-4071.928	3038.927
TO	38.00589	21.60089	1.76	0.094	-7.052778	83.06455
D1992	18.87985	15.14736	1.25	0.227	-12.71698	50.47668
_cons	121.4906	187.8897	0.65	0.525	-270.4405	513.4217

Note: The critical values are within parenthesis (5% level of significance).

Source: Own calculation.

4.6.4 Short Run Results-Parsimonious Model

If variables are cointegrated, then an error-correction model can be specified to link the short-run and the long-run relationships.

Table 10: Estimation results-Parsimonious ECM of the Agriculture TFP in Kenya

Source	**SS**	**df**	**MS**			**Number of obs = 25**
Model	1806.22878	6	301.038129			F(6, 18) = 1.66
Residual	3259.94938	18	181.108299			Prob > F = 0.1878
Total	5066.17816	24	211.090757			R-squared = 0.3565
						Adj R-squared = 0.1420
						Root MSE = 13.458
logtfpindex	**Coef.**	**Std. Err.**	**t**	**P>|t|**	**[95% Conf.**	**Interval]**
dlogRc	-0.4254105	3.192643	-0.13	0.895	-7.132906	6.282085
logWr	-18.52737	18.28061	-1.01	0.324	-56.93351	19.87877
dTO	70.74677	27.10887	2.61	0.018	13.79316	127.7004
dIirr	-1158.554	1828.191	-0.63	0.534	-4999.441	2682.334
D1992	39.50515	19.44382	2.03	0.057	-1.344803	80.35511
ect1	0.3102361	0.3376702	0.92	0.37	-0.3991826	1.019655
_cons	133.3144	174.1321	0.77	0.454	-232.5235	499.1523

Note: The critical values are within parenthesis (5% level of significance).

Source: Own calculation.

Residuals from the cointegrating regression are used to generate an error correction term (lagged residuals) which is then inserted into the short-run model. The estimates of the parsimonious error-correction model are presented in the following table. The results of the parsimonious ECM model are similar to the more complex model. According to the results, the only significant determinant of agriculture TFP (log TFP) is Trade Openness (TO).

5.0 SUMMARY OF FINDINGS, CONCLUSION AND POLICY IMPLICATIONS

5.1 Summary of Findings

It is found that the variables are non- stationary in levels but become stationary after the first differencing and de trending. Results from the Engle-Granger two step procedure indicate that the variables were co-integrated.

In the long run, Public R&D expenditure, Private R&D expenditure, and foreign funding were insignificant determinants of agricultural sector Total Factor Productivity. The same could be examined of the other factors examined. However, in the short run, changes in Trade openness were found to be a significant determinant of Total Factor Productivity in the agriculture sector.

Finally, the error- correction term is positively and insignificantly associated with changes to Total Factor Productivity signifying non-convergence to the long run equilibrium.

5.2 Conclusions

Failure of the coefficient of public R&D investment to explain the agricultural sector Total Factor Productivity in the long run can be attributed to the insignificant amounts that the government allocates to agricultural sector for research purposes. For actual proportions of budgetary allocation to the agricultural sector for the last four years, please refer to Table 1 in chapter one. This issue has also been noted in the discussion following the signing of the Comprehensive Africa Agriculture Development Programme (CAADP) which seeks to bind African governments to increasing public investment in agriculture to a minimum of 10% of their national budgets and to raise agricultural productivity by at least 6% per annum, with the ultimate aim of eliminating hunger and reducing poverty.

The study also concludes that the probable reason why private R&D expenditure and foreign funding were not significant determinants of agriculture TFP, is because of lack of interaction between the Government, the private sector, academic, research institutions and farmers, and the subsequent failure in commercialization of research findings. However, this interaction variable was not included in the model.

Trade openness seems to have a short run impact on agricultural sector performance. Consequently, it is advocated by this study that the government should follow a trade liberization oriented approach to the agricultural sector as opposed to a trade tightening approach.

5.3 Policy Recommendations

This study recommends the institutionalization of policies aimed at ensuring interaction between the various stakeholders in the agricultural sectors. This interaction will ensure that resources are better allocated to reduce duplication of research and dissemination activities. In addition, greater collaboration among the stakeholders will promote and strengthen the connection between research, policy and the application of research findings. In so doing, positive changes in public R&D expenditure, Private R&D expenditure, and foreign funding, would have significant impact on agricultural productivity.

It is also advocated by this study that the government should follow a trade liberization oriented approach to the agricultural sector as opposed to a trade tightening approach. However, this approach needs to be adopted carefully as it would still fail due to capacity constraints brought about by poor price incentives. Therefore, such a policy would be most effective if farmers' value added their produce so as to fetch and command better prices in international and regional markets. Failure to do this would result in poor utilization of trading opportunities such as those provided by the African Growth and Opportunity Act (AGOA).

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