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Agricultural Research and Development Expenditure, Productivity and Adoption as a Panacea to Improved Rural Livelihoods; A Review of Literature

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Abstract

Myriad of studies have been undertaken to evaluate contribution of agricultural research and development to improved rural livelihoods. Whether be it through influencing farm productivity, rural household income, employment creation and consumer welfare, agriculture research and development has been idealised to have a significant impact on livelihoods. This paper reviews past studies that have been undertaken in relation to agricultural research and development expenditure, factor input productivity and adoption by the rural poor in different agricultural aspects. The study identifies that there are some consistencies in reported findings of research and development expenditure having impact on improving agricultural output. Equally so, findings have also been consistent of agricultural productivity increasing at the instigation of research and development as well as the existence of an array of socio-economic factors having major influences on research and development innovation adoption. Despite the existence of spatial as well as temporal variations however, there do appear loopholes within the literature. Expenditure influences on output have appeared aggregated, with few studies, mainly from global research institutes, trying to subdivide how project specific expenditure has tended to influence the specified projects. Furthermore, studies on productivity measures of research and development despite being aggregated, have concentrated on how output has changed vis-à-vis changes in inputs utilised induced by research and development. A short fall however are studies based on the dynamism of the inputs relative to changes in output that they do instigate. Even the socio-economic variables tending to influence research and development output adoption appear to vary from technology to technology, in some instance having a positive influence and in other instances otherwise. Each project is thus unique and no array of diversification of socio-economic variables can be prescribed even though commonality could be identified.

Keywords: Adoption; Agriculture; Expenditure; Livelihoods; Research and development; Productivity.

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1. Introduction

Agriculture is a pillar for sustained development, poverty alleviation and enhanced food security in many third world countries (Olwande *et al.*, 2009). It is also quintessential in stimulating growth in other sectors within the economy. However, productivity of agriculture has witnessed a downward trend, with poverty increasing. This is at variance with one of the Millennium Development Goals (MDGs) of reducing the share of people suffering from extreme poverty and hunger by 50% come the year 2015. The year has come and gone and, alas, poverty and hunger have not reduced but actually increased. The most notable failure has been in Sub Saharan Africa (SSA) where agricultural productivity has dawdled behind than any other region in the world, well below food security and poverty reduction levels. Increasing productivity thus becomes imperative, not only to catch up with the MDGs but also for sustained livelihoods and economic development. A major proponent for achieving sustained livelihoods through reduced poverty and improved accessibility to food is through appropriate research and development (R & D) led agricultural technologies (Olwande *et al.*, 2009).

Agro-based research in SSA and the world over has had a huge impact in improving livelihoods through enhancing productivity growth giving rise to improved rates of return on investments (Alene and Coulibaly, 2008; Thirtle *et al.*, 2003). Lipton (1977) cited in Thirtle *et al.* (2003) instigated this proposition based on the fact that agriculture employs the majority of the rural poor and thus pro-labour-R&D-based agricultural growth goes a long way in improving livelihoods. This depends on the poor having little land or capital, with their income depending on increasing employment. Mello (2001), argues to the contrary, based on notion that it actually increases incomes for rural households, rather than employment, when they sell their produce, with a multiplier of reducing rural to urban migration, further enhancing development within the rural areas. Thirtle *et al.* (2003), supports this, further highlighting that increase in productivity leads to access to nutritional foods, rural poor empowerment through enhanced decision making and “asset accumulation” adapting them to economic shocks.

There is limited research that supports averments of increased agricultural R & D improving productivity and consequently reducing poverty (Thirtle *et al.*, 2003). Most notable has been by Ravallion (1998); Ravallion and Datt (1999) as well as Fan *et al.* (1999) in India. They discovered that higher agricultural wages and higher yields tend to reduce poverty, with lower farm productivity, lower rural living standards, lower literacy rates experiencing less pro-poor growth, as well as investments in roads and agricultural R & D and extension, which apart from increasing incomes, had effect on wage increases and lower food prices. In Minten and Barrett (2008) found out that adopting agricultural R&D induced technologies improved crop yields with consequence of lowering food prices, improving real wages for the unskilled labour and better welfare indicators. Alene and Coulibaly (2008), highlighted that in sub-Saharan Africa, agricultural R&D had a rate of return of 55%, with an annual reduction of the rural poor of 0.8% and its subsequent doubling would reduce poverty by 9% annually. It is therefore imperative that program-specific-appraisals be undertaken to pin point how these have impacted their intended beneficiaries. In South Africa, the National Cultivar Trials (NCTs) have shown that R&D has attributed R1.35 billion between 1977 and 2012, representing 4% of the gross value of field crop production. The country had a rate of return of R40 for every R1 invested in R&D. This had been mainly attributed to maize R&D.

Thirtle *et al.* (2003), indicates that more than 90% of the world poor live in South Asia, East Asia and SSA. Though poverty has declined in Asia from 1987 – 98, it increased in SSA, and most live in rural areas. The worst of the poor have little to no land and disproportionately gain from employment created by agricultural growth, and lower food prices, as do their urban counterparts, who spend much of their income on food (Thirtle *et al.*, 2003). Implicitly, agricultural growth positively impacts on poverty, because of its overarching nature, unlike growth in the services and manufacturing sector.

Research-led technological change has rendered famine-plagued, food insecure Asian countries into food self-sufficiency (Thirtle *et al.*, 2003). This provides a base upon which the world over, and especially third world countries, can emulate to overcome the quagmire of extreme poverty and reduced livelihoods. Adato and Meizen-Dick (2002), aver that the livelihoods concept conceptualizes poor people economic activities. Diverging from the access to jobs and employment premise in the 1970s, strategy and reality of rural poor poverty reduction has been premised on the simultaneous pursuit of an array of simultaneous activities, by different family members, utilising different resources to take advantage of different opportunities at different times. It is therefore imperative to understand how these multiple activities, sources of vulnerability, institutions and structures, developmental interventions may influence these livelihood activities (Adato and Meizen-Dick, 2002).

A comprehensive evaluation of the literature is thus indispensable in highlighting the current thoughts on the subject of R & D and its impacts of rural livelihoods. The literature provides theoretical reasoning and piecemeal empirical evidence on the impact of agricultural growth on poverty reduction (Thirtle *et al.*, 2003). The following section will dissect the research and development epitome on the basis of its influence on livelihoods, productivity and socio-economic variables influencing its adoption. For embodiment, an array of research and development outputs or processes have been utilised to capture a fuller portrait on the ground.

2. Method

The study was an archival design pertaining to a review of literature and "grey" literature on agricultural research and development expenditure, factor input productivity and adoption by the rural poor in different agricultural aspect. The study initially conducted a literature search on Taylor and Francis as well as Elsevier journal databases utilising key words such as "research and development", "agriculture", "expenditure", "productivity", "small scale", "small-holder" and "communal" and "rural livelihoods). The literature search and review was also search was expanded to incorporate Google Scholar search engine, as well as Google. The study utilised 30 journal articles, 1 government report, 8 institutional reports, 2 book chapters and 3 conference proceedings. Thematic analysis was used in the study.

3. Agricultural Research and Development Expenditure and its Influence on Rural Livelihoods

Agricultural R & D systems in most third world countries were inherited from colonial powers (Alene and Coulibaly, 2008). It mainly regarded export products, especially by commercial farmers, at the expense of subsistence farmers. Independence of these countries brought in a new era of intense commercialisation of the agriculture system with export orientation as well as employment creation. During this time, donor induced R & D was utilised to prop commercial farming as a hub for growth. However, as the dust settled, there were growing concerns of the effectiveness of export-oriented growth and its impact on poverty and inequality (Alene and Coulibaly, 2008). This brought the small holder farmer to the fray, especially with regards to R & D induced poverty alleviation.

According to Evenson (2001) by the beginning of the twentieth century, most of todays developed countries had agricultural systems in place. By the middle of the 20th century, many of today's developing countries had followed suit. Alene and Coulibaly (2008), found out that R & D expenditure in Sub Saharan Africa increased from US$1.2 billion (2000 real international dollars) in 1980 to US$1.67 billion in 2003. The number of researchers increased likewise from 5000 full time equivalent (FTE) researchers in 1980 to over 12000 FTE researchers in 2000. However, the increase has not been congruent and has resulted in reduced operational budgets per scientist and in research inefficiency.

Various studies have been undertaken to establish relationship between public agricultural research investment and growth in agricultural productivity. Few have actually tried to compare how public investment has fared albeit private investment in research and development. This is so crucial given the dynamics of private investment far outstripping public investments. Lee *et al.* (2011) in Inglesi-Lotz and Pouris (2013) indicate that relative significance of research investment depends on a country's development stage, where it has more economic impact in developing countries. This was supported by Inekwe (2014) who found that research and development expenditure had a beneficial impact. However, the effect of research and development spending on growth is insignificant in low income countries but higher in upper and middle income countries.

Wang *et al.* (2013), highlighted that it is difficult to distinguish private and public research and development on the fact that they both compete with each other, with marginal cost provision of public research and development overshadowing private investments. This was supported by Alfranca and Huffman (2001) cited in Wang *et al.* (2013) of an antagonistic relationship between public investment and private investment in agricultural research and development. Conversely, Wang *et al.* (2013) also highlighted that public and private investments could be complementary. In this view, there is creation of a chain in research and development where the public investments are mainly aimed at pre/post commercial investment, with the private investments aimed at the commercial spectrum. In their study in the US, Wang *et al.* (2013) found that there was responsiveness in both public and private research and development investments relative to what the other was doing, and the two tended to complement each other.

Some of the recent and pertinent studies that have been undertaken to relate agricultural R & D expenditure to agricultural output are outlined in table 1 below

Table-1. Literature on R & D expenditure and its influence on livelihoods

Author	Focus	Approach	Summary of findings
Gallup *et al.* (1998)	Economic growth and the income for the poor	Cross country examination of the relationship between growth and poverty	A 1% increase in agricultural GDP led to a 1.61% increase in income of the poorest quantile, with manufacturing managing 1.16% and services sector 0.79%
Fan *et al.* (1999)	Linkages between government spending, growth and poverty	Identify different channels through which government expenditure affects the rural poor in India through simultaneous econometric modelling	Agricultural R & D had great influence on increasing incomes, wage increases, lower food prices
Adato and Meizen-Dick (2002)	Impact of agricultural research on poverty using the sustainable livelihoods framework	Multimethod research on the livelihoods framework on case studies on modern rice varieties in Bangladesh, polyculture fishponds and vegetable gardens in Bangladesh, soil fertility practices in Kenya, hybrid maize in Zimbabwe, creolized maize varieties in Mexico	Identified the livelihoods framework as more appropriate approach to addressing poverty. It introduces many factors and relationships often missing form convectional reductionist approaches. Agricultural research and development may not play a central role when peoples livelihoods picture is taken in *toto* but understanding the full picture can help develop technologies that better fit with the complex livelihood strategies
Thirtle *et al.* (2003)	Impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America	Utilised the World Banks $1 per day poverty survey of 121 African, Asian and Latin American countries to assess impact of agricultural growth, agricultural R & D expenditures, agricultural productivity growth on $1 per day, GDP per capita, inequality and poverty reduction comparably to industry and services	Investment in agricultural R & D raises agricultural value added sufficiently to give satisfactory rates of return, in both Africa (22%) and Asia (31%), but not in Latin America (10%). Thus, in two continents, agricultural R & D pays for itself, as increased results in broad-based growth, which reduces poverty. A 1% increase in yields reduces the number living under $1 per day poverty by 6¼ million, with 95% of these in Africa and Asia. The cost of removing one individual from $1 per day poverty in Africa is $144, in Asia $180, but in Latin America is over $11 000.
Minten and Barrett (2008)	Link between agricultural performance and rural poverty in Madagascar	Commune level census in 2001, national census in 1993 and geographical secondary data	Strongly favours supports of improved agricultural production as an important part of any strategy to reduce poverty and food insecurity. High rate of adoption of improved agricultural technologies leads to high crop yields
Alene and Coulibaly (2008)	Impact of agricultural research on productivity and poverty in sub-Saharan Africa	Polynomial distributed lag structure for agricultural research within a simultaneous system of equations	Agricultural research contributes to productivity growth. Productivity growth raises per capita income, income increase influencing poverty reductions. Agricultural research had 55% rate of return. Agricultural research reduces number of poor by 2.3 million or 0.8% annually. However, this is far below the poverty-increasing effects of population

			growth and environmental degradation. Doubling research investments in SSA would reduce poverty by 9%. But ancillary services of efficient extension, credit and input supply systems required to realize this effect
Agricultural Research Council (2014)	The Value of National Cultivar Trials (NTCs) in South Africa from 1977 to 2012	Quantification of the economic value of the NCTs for maize, sorghum, sunflower, soybeans and dry beans	NCTs facilitated farmer's abilities to identify, compare and select summer grain crops in different regions and bio-environments in key summer grain crops. Increased grain output was induced through investments in germplasm research, improved agronomic and cultural practices and advisory services, and the use of hybrid seeds and nitrogen fertiliser.
Liebernberg *et al.* (2011)	South African agricultural R & D investment sources, structure and trends	Trend analysis of agricultural R & D from 1910 to 2007 in South Africa	Research spending grew by 5.1% from 1911 to 1950, and by 7% from 1950 to 1971 and ceased growing. During the 1950s and 1970s, spending on agricultural R & D grew faster than agricultural output, with intensity on investment in public research (i.e. agricultural R & D spending as a share of agricultural GDP) increased from 0.8% in 1911 to 2.46% in 1983, relatively flatting out over the next years and reaching 2.5% by 2007
Lawal (2011)	Government spending on agricultural sector and its contribution to GDP in Nigeria	Trend analysis and linear regression	Found out that government spending does not follow a regular pattern and that the contribution of the agricultural sector to GDP is in direct relationship with government funding to the sector
Iganiga and Unemhilin (2011)	Impact of Federal Government Agricultural Expenditure on Agricultural Output in Nigeria	Co-integration and Error Correction Model were used to analyse long run and short run dynamic impact of government expenditure on agricultural output	Impact of government expenditure is not instantaneous and is felt in the long run. Showed that a 10% increase in capital expenditure leads to 4.31% increase in agricultural output
Pardey *et al.* (2012)	Agricultural production, productivity and R & D over the past 50 years	Review of literature and secondary data	Agricultural R & D worldwide is changing. In the world as a whole, crop yield growth has slowed. In high income countries productivity growth has slowed significantly, real spending on agricultural R & D is being reduced. Middle income countries are growing in relative importance as producers of agricultural innovations through investment in R & D, with better prospects as producers of agricultural products

Gallup *et al.* (1998), indicated that a 1% increase in agricultural GDP led to a 1.61% increase in income of the poorest quartile, with manufacturing managing 1.16% and services 0.79%. In Africa, Asia and Latin America, Thirtle *et al.* (2003) found out that investment in agricultural R & D raises agricultural value added by 22%, 31% and 10% respectively. Furthermore, a 1% increase in yields reduces the number living under $1 per day poverty by 6¼ million, with 95% of these in Africa and Asia. However, the cost of removing one individual from $1 per day poverty in Africa is $144, in Asia $180, but in Latin America is over $11 000 (Thirtle *et al.*, 2003). Alene and Coulibaly (2008) support agricultural research contributing to productivity growth consequently raising per capita income ultimately influencing poverty reduction. They highlight that agricultural research had a 55% rate of return and reduced the number of poor by 2.3 million or 0.8% annually. A 50% increase in R & D investments – by one international dollar per hectare – would reduce poverty by 4.65% or 14 million poor (Alene and Coulibaly, 2008). Though plausible, returns are far below the poverty-increasing population growth and environmental degradation effects. Doubling research investments in SSA would reduce poverty by 9%, but ancillary services of efficient extension, credit and input supply systems were required to realize this effect (Alene and Coulibaly, 2008).

The literature above empirically indicated that increasing research and development expenditure has a positive effect on improving livelihoods, especially for the poor. Liebernberg *et al.* (2011) is however of the opposite effect by highlighting that in South Africa during the 1950s and 1970s, when research expenditure grew by 5.1% and 7% respectively from the 1911 levels, agricultural spending far outweighed increase in agricultural output, with intensity on investment in public research (i.e. agricultural R & D spending as a share of agricultural GDP) increasing from 0.8% in 1911 to 2.4% in 1983, relatively flatting out over the next years and reaching 2.5% by 2007 (Liebernberg *et al.*, 2011). In Nigeria, Lawal (2011) realized that government expenditure does not follow a regular pattern and that the contribution of the agricultural sector to GDP is in direct relationship with government funding to the sector. Iganiga and Unemhilin (2011), support this further indicating that the impact of government spending is not instantaneous and is felt in the long run. They identified that in Nigeria, a 10% increase in capital expenditure led to a 4.31% increase in agricultural output (Iganiga and Unemhilin, 2011).

Agricultural R & D has a great influence on increasing incomes, wage increases and lower food prices (Fan *et al.*, 1999). Minten and Barrett (2008), strongly supports improved agricultural production as an important part of any strategy to reduce poverty and food insecurity. High rate of adoption of improved agricultural technologies leads to high crop yields. In South Africa, the National Cultivar Trials (NCTs) facilitated farmers' abilities to identify, compare and select grain crops in different regions and bio-environments. Increased grain output was induced through investments in germplasm research, improved agronomic and cultural practices and advisory services, and the use of hybrid seeds and nitrogen fertilisers (Agricultural Research Council, 2014; Dlamini *et al.*, 2015). Adato and Meizen-Dick (2002), managed to put the livelihoods framework in the agriculture research and development debate indicating that the framework was a more appropriate approach in addressing poverty by introducing many factors and relationships often missing from convectional reductionist approaches. Agricultural R & D may not play a central role when people's livelihoods picture is taken in *toto* but understanding the full picture can help develop technologies that better fit with the complex livelihoods strategies (Adato and Meizen-Dick, 2002).

Agricultural R & D worldwide is changing (Pardey *et al.*, 2012). In the world as a whole, crop yield growth has slowed. In high income countries, productivity growth has slowed significantly; real spending on agricultural R & D is being reduced. Middle income countries are growing in relative importance as producers of agricultural innovations through investment in R & D with better prospects as producers of agricultural products (Pardey *et al.*, 2012).

The above identified literature, which identifies the relativeness of agricultural R & D expenditure to rural livelihoods, does however unmask its own flaws. Most of the studies take a generalist approach. They broadly mask agricultural R & D industry specific expenditure and performance thereof. For instance, there is no thin line between livestock specific or crop specific research. Research and development expenditures thereof are likely to have differing outcomes and effects on their intended beneficiaries. The literature does not also demarcate which agricultural R & D expenditure outperformed the other in terms of public and private expenditure. Private R & D expenditure is likely to be more and likely have more impact given the research output from private institutions and the push and drive of their innovativeness given the need to recoup capital investments in their research endeavours. This puts to light the need for project specific R & D expenditure scrutiny which is far below the idealised to illuminate and further corroborate the findings in the literature. The findings from the above literature are also conspicuous as they do not provide a direct relationship through cause and effect time series data to show the effects of R & D expenditure on livelihoods. Research and development impacts are unlikely to be instantaneous as the literature paints it to be, there are likely to be lags in time before R & D expenditure and its effects thereof take shape and effect and the studies tend to shove that aspect under the blanket. Though helpful, such studies should be cautiously taken into consideration, and they also offer a gap in literature that can be pursued.

4. Factor Input Productivity of Research and Development and its Impact on Rural Livelihoods

Raising agricultural productivity and reducing poverty can be achieved through agricultural research, a point in case being the 1960s and 1970s green revolution (Alene and Coulibaly, 2008). However, most of the evidence has been theoretical, with limited empirical evidence establishing agricultural R & D, productivity growth and poverty. Much of the empirical work done has concentrated on aggregate agricultural productivity, and has shown consistency in reporting increase in average productivity in the 1960s, depressed productivity in 1970s and increased productivity in 1980s and 90s (Coelli and Rao, 2005; Fulginiti *et al.*, 2004; Nkamleu, 2004). Yet, little analysis has been done to explain the measured productivity changes and ascertain the contribution of agriculture R & D to productivity growth (Alene and Coulibaly, 2008).

An array of studies have been undertaken to ascertain factor input productivity as shown in table 2 below.

Table-2. Literature on factor input productivity of R & D expenditure and its impact on livelihoods

Author	Focus	Approach	Summary of findings
Thirtle *et al.* (1998)	Rate of return on expenditures of the South African Agricultural Research Council	Utilized index number to construct TFP index from South African agriculture. Explaining TFP with R & D, extension, patents, farmer education and the weather led to estimates of the returns of agricultural research and extension	There is need for strong socio-economic component to the ARCs efforts if it is to reach the disadvantaged

Thirtle *et al.* (2003)	Impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America	Utilised elasticities of value-added per unit of land with respect to agricultural R & D to calculate rate of return to agricultural R & D	82% of the variance in land productivity is explained by R & D expenditures, inputs of fertilizers and labour (machinery was not significant), a land quality index and illiteracy. Labour has high, large and significant elasticities for Africa and the Americas, but insignificant for Asia, reflecting labour surplus. Machinery is significant only for Africa. Land productivity and land labour ratio were significant in Asia and Americas
Huffman (2009)	Measuring public agricultural research capital and its contribution to state agricultural productivity	Total Factor Productivity (TFP)	Found out that public agricultural research capital contributes significantly to agricultural productivity. Showed that intraregional and spill-in public agricultural research capita is complementary whilst private agricultural research capital and public extension are substitutes. Public agricultural research had a high marginal social rate of return
Rahman and Salim (2013)	Total factor productivity change and sources of growth in Bangladesh Agriculture	Applied the Färe-Primont index to calculate TFP indices for agriculture in 17 regions of Bangladesh from 1948 – 2008. TFP index was decomposed into 6 finer components (technical change, technical scale and mix efficiency changes, residual scale and residual mix efficiency changes)	TFP grew by 0.5% p.a. powered by technological progress estimated at 0.74% p.a. technical efficiency improvement was negligible (0.01% p.a.) with a high decline in mix efficiency (0.19%) p.a. Farm sizes, R & D investment, extension expenditure, and crop specialization positively influenced TFP growth whereas literacy rate had a negative influence on growth
Agricultural Research Council (2014)	The Value of National Cultivar Trials in South Africa from 1977 to 2012	Quantification of the economic value of the NCTs for maize, sorghum, sunflower, soybeans and dry beans	The program added 7.67 kg/ha/yr. for sorghum and 24 kg/ha/yr. for maize. Economic benefit of 4% of gross value of production of field crops in South Africa in 2010, 1% of gross value of all agricultural production. South African economy had R40 of benefit for each R1 invested by ARC in the trials. Maize was 10% of the total 2010 gross value of maize production. For every rand spent on the trials, the South African 1977 to 2012 economy benefitted: • R2.84 for sunflower • R4.97 for dry beans • R4.96 for soybeans • R3.19 for sorghum However, most of the trials where in large commercial farms, except for some limited dry beans in small holder areas
Hurley *et al.* (2014)	Re-examining the reported rates of return to food and agricultural research and development	Utilised modified internal rate of return instead of internal rate of return to scrutinize 2 242 investment evaluations reported in 372 separate studies from 1958 to 2011	The marginal rate of return was 9.8% instead of the internal rate of return which overestimated it at 39% per year in the US
Dlamini *et al.* (2015)	Estimating the economic value of the national cultivar trials in South Africa: A Case for sorghum, sunflower, soybeans and dry beans from 1978 - 2012	Utilised attribution methods to estimate yield losses prevented by providing farmers with information that has facilitated the selection of adapted cultivars in their localities. Secondary data utilised from past publications	Find that yield benefits are equivalent to 13.10 kg and 7.67 kg for sunflower and sorghum output per hectare per year respectively, whilst soybean and dry bean trials contributed yields equivalent to 16.42 kg and 17.13 kg per hectare per year respectively. The estimated total economic benefit that have accrued to South Africa over period 1978 – 2012 amounted to R 200 million in 2012

			prices, equivalent to 4% of total gross value of production of these crops in 2012. Of these benefits, about R23.2 million came from the evaluation of sunflower cultivars, R84.7 million from dry beans, R85.7 million from soybeans and R6.6 million from the evaluation of sorghum cultivars. The assumed yield gain over the period was 13.10% for sunflower, 17.13% for dry beans, 16.42 for soybeans and 7.67% for sorghum (at the 5% sig, level). Benefit to cost ratio of cultivar contribution where 0.71% for sunflower, 5.14% for dry beans, 4.95% soybeans, 0.52% sorghum (at 5% sig. level). The overall rate of return to investments in the national cultivars trials is 17% for sunflower, 16% for dry beans, 33% for soybeans, and 10% for sorghum. A sensitivity analysis to a change in the discount rate to rate of return to investments shows that sunflower is 20% responsive, dry beans are 23.08% responsive; soybeans are 8.58% responsive whilst sorghum was 53.85% responsive.

Thirtle *et al.* (2003), utilised elasticities of value added per unit of land with respect to agricultural R & D to calculate the rate of return to agricultural R & D. In this case the output gains over time are set against the R & D costs. They found out that 82% of the variance in land productivity is explained by R & D expenditure, inputs, labour, land quality index and illiteracy. They found labour having high, large and significant elasticities for Africa and the Americas, but insignificant for Asia, reflecting labour surplus. Machinery was significant only for Africa. Land productivity and land labour ratio were significant in Asia and the Americas (Thirtle *et al.*, 2003). Rahman and Salim (2013), applied a Färe-Primont index to calculate Total Factor Productivity (TFP) indices for agriculture in 17 regions of Bangladesh from 1948 to 2008. The TFP index was decomposed into 6 finer components namely technical change, technical scale and mix efficiency changes, residual scale and residual mix efficiency changes. They identified TFP growing by 0.5% per annum being powered by technological progress estimated at 0.74% per annum (Rahman and Salim, 2013). However, technical efficiency improvement was negligible at 0.01% per annum, with a high decline in mix efficiency at 0.19% per annum. Farm sizes, R & D investments, extension expenditure and crop specialization positively influenced TFP growth whereas literacy rates had a negative influence on growth (Rahman and Salim, 2013). Huffman (2009), also utilised the TFP to measure public agricultural research capital and its contribution to state agricultural productivity and established that public agricultural research capital contributes significantly to agricultural productivity. Furthermore, intraregional and spill-in public agricultural research per capita is complementary whilst private agricultural research capital and public extension are substitute. Public agricultural research had a high marginal social rate of return (Huffman, 2009). In the US, Hurley *et al.* (2014) indicated that marginal rate of return was 9.8% per annum relative to the overestimated internal rate of return reported at 39% per annum from 1958 to 2011 when they were re-examining the reported rates of return to food and agricultural R & D in the US.

In South Africa, utilising attribution methods, Dlamini *et al.* (2015) estimating economic value of National Cultivar Trials (NCTs) for sorghum, sunflower, soybeans and dry beans from 1978 to 2012, found that there were improvements per hectare of 13.10 kg, 7.67 kg, 16.42 kg and 17.13 kg for sunflower, sorghum, soybean and soybean respectively. They found that total economic benefit accrued to South Africa over the period 1978 to 2012 amounted to 4% of total production of these crops in 2012. The assumed yield gain over the period was 13.10%, 17.13%, 16.42% and 7.67% for sunflower, dry beans, soybeans and sorghum respectively. The benefit cost ratio for sunflower, dry beans, soybeans and sorghum were 0.71%, 5.14%, 4.95% and 0.52% respectively. The overall rate of return for the investments in the NCTs was 17% for sunflower, 16% for dry beans, 33% for soybeans and 10% for sorghum. Through a sensitivity analysis of altering the discount rate utilised in the rate of return calculation, it was established that sunflower was sensitive by 20%, dry bean by 23.08%, soybean by 8.58% whilst sorghum was at 53.85% (Dlamini *et al.*, 2015). Agricultural Research Council (2014) corroborate Dlamini *et al.* (2015) findings by indicating that research and development of the NTC's had an economic benefit of 4% of gross value of production of field crops in South Africa in 2010, 1% of gross value of all agricultural production. Furthermore, the South African economy had a R40 benefit for each R1 invested by the ARC in the trials. For every rand spent, the South African 1977 to 2012 economy benefited R2.84 for sunflower, R4.97 for dry beans, R4.96 for soybeans and R3.19 for sorghum.

The above studies highlight that though much increase in agricultural output has been attributed to improvements through R & D, it still has short falls as indicated for R & D expenditure studies. The findings appear aggregated. There is also a scope short fall where most of the studies appear to encompass most of the commercial side of agricultural production much to the detriment of the small holder. Agricultural Research Council (2014) support this notion indicating that most of the trials where in large commercial farms, except for some limited dry beans studies in small holder areas. Thirtle *et al.* (1998), further adds the need for strong socio-economic components in assessing the returns of R & D output especially at the disadvantages, which previous studies do not seem to cover.

It is also worth noting that in most studies productivity in essence tends to relate output to inputs. Little research actually tries to evaluate how introduction of R & D output could actually influence the factor of production mix within individual enterprises. Thirtle *et al.* (2003) tried to address this shortfall by assessing the land productivity against R & D introduced but still the aggregated study could not provide how the whole factor input of production mix fared relative to each other. Marginal productivity of each factor of production will thus offer an encompassing means by which to assess how the introduction of R & D output could have influenced their mix. Hurley *et al.* (2014), findings support such a proposition, where contrasting and conflicting internal rate of return and marginal rate of return measures where shown. It therefore offers a gap in literature where studies relating to factor of production mix and how each marginally performed relative to each other could be incorporated to assess impact of R & D on agricultural production.

5. Improved Rural Livelihoods through Research and Development Adoption

Agricultural R & D investments have generated a range of improved technologies (Alene and Coulibaly, 2008). In Sub Saharan Africa, modern R & D output was only utilised in 1% of crop area. The utilisation of R & D grew in the 1980s throughout to the 1990s. For instance, 26% of the area in SSA in 1998 was grown with improved cultivars. Wheat had increased by 52% whilst rice, maize, potatoes, sorghum and cassava had increased by 40%, 47%, 78%, 26% and 18% respectively (Alene and Coulibaly, 2008). However, the improved adoption rate did not match production growth, as only 0.6% growth per year for the last four decades has been attributed yield growth relative to 1.9% attributable to area expansion. Broad based technological change induced through agricultural R & D benefits the rural poor in a variety of ways: First, it raise incomes or home consumption for those who adopt new technologies; secondly, positive impact on real income of others through lower food prices, increased employment and wage effects and other agro related industries through production, consumption, and savings (Alene and Coulibaly, 2008).

A vast of adoption studies have been undertaken cutting across the whole spectra of agricultural R & D induced innovations as shown in Table 3.

Table-3. Literature R and D adoption and its influence on livelihoods

Author	Focus	Approach	Summary of findings
Purvis *et al.* (1995)	Technology adoption decisions under irreversibility and uncertainty	Empirical analysis on Texas dairy producers' propensity to adopt free-stall dairy housing	Uncertainty and irreversibility about costs and environmental compliance are important determinants in dairy investments
Croppenstedt *et al.* (2003)	Technology adoption in the presence of constraints: the case of fertiliser demand in Ethiopia	National data set through a double-hurdle fertiliser adoption model	Access is major constraint in four zones; credit is a major supply-side constraint. Household size, formal education of the farmers, value to cost ratio are major demand side with major impact on adoption of fertiliser use. Recommended reducing costs of procurement, marketing and distribution of fertiliser
Thirtle *et al.* (2003)	Impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia and Latin America		Found out that technology generated is not the main problem but the extension required to reach the farmers, with inputs, credit, output sold, markets access, institutional and organizational development and infrastructure major bottlenecks in adoption
Amsalu and De Graaf (2007)	Determinants of adoption and continued use of stone terraces for soil and water conservation in Ethiopia	Survey of 147 farming households using bivariate probit	Adoption is influenced by farmer's age, farm size, perception on technology profitability, slope of land, livestock sizes and soil fertility. Decision to continue using the practice is influenced by actual technology profitability, slope, soil fertility, family size, farm size and participation in off-farm work. Factors influencing adoption and continued use are not the same. Concluded that analysis of determinants of adoption per se may not provide a full understanding of the range of factors influencing farmers decision of sustained

			investments
Knowler and Bradshaw (2007)	Farmer's adoption of conservation agriculture	Review of literature and secondary data	Find few universal variables that regularly explain the adoption of conservation agriculture across past analyses. Some of the factors identified as influencing adoption of conservation agriculture include (1) farmer and farm household characteristics: age, education, health, experience, gender, unmet basic needs, innovativeness index, attitudes towards conservation, risk bearing index, degree of control of decision making, expected yields threat, management knowledge, connectedness, leadership status, future orientation, dependency ratio, home equipment; (2)farm biophysical characteristics: farm size, area planted, farm fragmentation, yield per hectare, sole, soil productivity, rainfall, distance to road, distance to market; (3) farm financial/management characteristics: tenure, family labour, hired labour, income, farm profitability, availability of machinery, expenditure on fuel, expenditure on fertilisers, non-agricultural wage, access to credit; (4) exogenous factors: input prices, output prices, interest rate, availability/ease of obtaining information, attendance at field demos and test plots, membership in organizations
Minten and Barrett (2008)	Link between agricultural performance and rural poverty in Madagascar		Strongly favours supports of improved agricultural production as an important part of any strategy to reduce poverty and food insecurity. High rates of adoption of improved agricultural technologies leads to lower food prices, high real wages for unskilled workers and better welfare indicators
Greiner *et al.* (2009)	Motivations, risk perceptions and adoption of conservation practices by farmers	Survey of 94 graziers in Burdekin River Catchment in Australia to explore and to what extent motivations and risk perceptions influence adoption of Best Management Practices (BMPs0	Found correlations between motivations and risk attitudes, and adoption of BMPs. The technologies were adopted by those graziers pursuing lifestyle and conservation goals and motivated to adopt conservation practices. Graziers with high economic/financial and social motivation have low levels of adoption as they require external incentives. Recognition by community of conservation efforts, serve as a powerful incentive particularly for socially motivated farmers. Extension, education and research play a role in the adoption process, especially where changes to current practices are comprehensive
Olwande *et al.* (2009)	Agricultural Technology Adoption	Panel analysis of farmers' fertilizer use in Kenya	Age, education level, credit, presence of a cash crop, distance to market, agro ecological potential, dependency ratio, distance to extension had major influence on fertilizer adoption
Derpsch *et al.* (2010)	Current status of adoption of no-till farming in the world and some of its main benefits	Estimates of numbers of technology adopters from informants in different countries	Barriers to adoption of no-till technology is influenced by the mind-set (tradition, prejudice); knowledge (know how); adequate policies to promote adoption, availability of adequate ancillary products (machines, herbicides)
Lamar (2010)	Adoption of conservation agriculture in Europe	Review of literature and secondary data in Europe	Drivers/constraints for adoption of conservation agriculture include (1) farm and market conditions: reduced/increased production costs, more/less flexibility and improved timeliness of operations (2) biophysical condition: favourable/unfavourable climate, favourable/unfavourable soils (3) social, cultural, technological, institutional and policy

			environments: leadership/lack of leadership from farmers and farmer organizations, presence/absence of crisis mentality, presence/absence of dynamic and effective innovation system, knowledge, policies affecting farm size, agrarian structure and land tenure,
Atibioke *et al*. (2012)	Effects of Farmers' Demographic Factors on the Adoption of Grain Storage Technologies Developed by Nigerian Products Research Institute (NSPRI). A Case Study of selected villages in Illorin West LGA of Kwara State	Survey of 120 respondents from 6 villages, and interviews with 10% of all farmers in each village. The study utilised descriptive statistics and logistic regression	There was significant relationship in using NSPRI technology with sex, level of education and occupation. Age of respondent, marital status, years of arming, farm size, farm acquisition, years of production, awareness, types of grain produced had no influence on adoption of the technology
Mustapha *et al*. (2012)\	Socio-economic factors affecting adoption of soya bean production technologies in Takum, Nigeria	Interview of 180 soya bean producers and analysed through multiple regression	Educational levels, farming experience and source of information had significant and positive influence on adoption of improved technology. The major constraints were poor extension services and lack of credit facilities
Corbeels *et al*. (2013)	Understanding the impact and adoption of conservation agriculture (CA) in Africa: A multi-scale analysis	Analysis of CA research, development and dissemination in SSA at different scales: field, farm, village and region	Adoption is influenced by horizon: where famers are more considerate of short term horizons of immediate need to provide for family with technologies earmarked for long term horizons. Good input supply markets and sale of produce are a prerequisite condition for widespread adoption of CA. studies in Brazil and India indicated that though some adoption is not realized from subsistence farmers, it is adopted by market oriented producers, changing focus. Adoption is influenced by farmers own understanding of principles, their aspirations and possibility of integrating them into their farming systems, and their access to knowledge, advice and resources. Too much concentration on demonstrating CA rather than adapting it to local conditions (climate, physical environment, market, etc.). there is need to of a multi-stakeholder approach through an innovation network (from farmers, extension agents, researchers, inputs suppliers, equipment manufacturers, service providers, traders, and policy makers for adoption of CA to local conditions
Rahman and Salim (2013)	Adoption of climbing beans	Survey to assess awareness, trial and adoption rates, insight into adoption process of farmers in the central Highland of Kenya from 550 respondents from 36 villages and45 interviewed	40% of the 90% of farmers who were aware of climbing beans had adopted it for at least one season and only 11% had maintained its production. Increasing age of the household head, contact with extension services and farmers to farmer transmission were significant for awareness and testing climbing beans
(Negash, 2015)	Drivers of bioenergy crop adoption	Utilised a double hurdle model from adapt of castor out grower scheme in Ethiopia	Shows that higher price of maize (a major staple crop) is strongly associated with lower size of land allocation to castor. Distance from village centres and number of visits by public extension agents do not influence decision to adopt
Maliki *et al.* (2016)	Sustainable Agriculture and innovation adoption in a small scale food production system	Survey of 27 villages in Benin utilising logistic regression of intercropping yam and maize producers	Identified contact with researchers and extension workers, population density in zone, credit service, gender, land, farm household and livestock sizes as major discriminatory factors

Croppenstedt *et al.* (2003), managed to differentiate the existence of supply-side and demand side constraints towards technology adoption by small holders in utilising fertiliser in Ethiopia. They identified credit as a major supply-side constraint and factors such as household size, formal education and value to cost ratio were major demand-side constraints. Thirtle *et al.* (2003), supports the supply-side constraints by indicating that factors such as access to extension, inputs, credit, selling output, market access, institutional and organizational development and infrastructure were major bottlenecks in adoption of new technology. In the dairy industry, Purvis *et al.* (1995) highlighted that uncertainty and irreversibility about costs was a major determinant in dairy innovation adoption. (Negash, 2015) identified factors such as price of substitute strongly influencing the size of land allocated to production of certain crops. Furthermore, distance from village centres and number of visits by public extension agents had no influence on decision to adopt (Negash, 2015).

Amsalu and De Graaf (2007), support the demand-side constraints to innovation adoption. They found factors such as farmer's age, farm size, perception on technology, profitability, slope of land, livestock sizes and soil fertility having a major influence on soil and water conservation technologies in Ethiopia. Furthermore, the decision to continue using the technology once introduced to it rested upon its profitability, slope, soil fertility, family size, farm size and participation in off-farm work.

Derpsch *et al.* (2010), disaggregated factors influencing adoption to the mind-set (tradition, prejudice), knowledge (know how), adequate policies to promote adoption and availability of adequate ancillary products (machines, herbicides). Knowler and Bradshaw (2007), partitioned the factors influencing adoption of technology, conservation agriculture in this case, to farmers and farm household characteristics, farm biophysical characteristics, farm financial or management characteristics and exogenous factors. Farmer and farm household characteristics such as age, education, health, experience, gender, unmet basic needs, innovativeness index, attitudes towards the innovation, risk bearing index, degree of control of decision making, expected yield threat, management knowledge, connectedness, leadership status, future orientation, dependency ratio and home equipment had major impact on innovation adoption (Atibioke *et al.*, 2012; Maliki *et al.*, 2016; Olwande *et al.*, 2009; Ramaekers *et al.*, 2013). Factors such as farm size, area planted, farm fragmentation, yield per hectare, soil productivity, rainfall, distance to road and distance to market were some of the major farm biophysical factors influencing technology adoption (Lamar, 2010). Farm financial or management characteristics that had major influences into technology adoption included tenure, family labour, hired labour, income, farm profitability, availability of machinery, expenditure on fuel, expenditure on fertilisers, non-agricultural wage and access to credit. Exogenous factors that tended to influence technology adoption pertained to input prices, output prices, interest rate, availability or ease of obtaining information, attendance to field demos and test plots and membership to organization. Though much of the findings pertained to conservation agriculture, conservatively it can be accepted across all agricultural aspects.

Greiner *et al.* (2009), found correlations between motivations, risks and attitudes with adoption of innovations in conservation agriculture in Australia. Lifestyles, goals and motivation led to innovation adoption. Economic, financial and social motivation led to lower levels of adoption as there would be requirement of external incentive to adopt. Lamar (2010) further adds that cultural, technological and policy environments such as leadership and its lack thereof from farmers and farmers organizations, presence or absence of crisis mentality, presence or absence of dynamic and effective innovation system also tend to influence technology adoption. Community recognition was a powerful incentive particularly for socially motivated farmers. Extension, education and research play a role in the adoption process, especially where changes to current practices are comprehensive (Greiner *et al.*, 2009).

A vast of studies have been undertaken in agriculture overall in determining factors considered in adopting new technologies and innovation. Most agricultural R & D studies have been based on adoption and impact of varieties of major food crops (Alene and Coulibaly, 2008). This vastness however also tends to illuminate some of the studies flaws. Amsalu and De Graaf (2007), are of the view that analysis of determinants of adoption may not provide a full understating of the range of factors influencing farmers' decision of sustained innovation adoption. In actual fact, (Knowler and Bradshaw, 2007) failed to find few studies with commonality in identified factors affecting technology adoption. It is quite interesting to note that there is no consensus amongst the differing authors. Even in highly related studies, the studies indicated the mix of socio-economic factors adjudicated as being highly influential to technology adoption to be different. Though commonality was identified to factors such as educational levels, household size and access to ancillary services, in more than one instance there has been no agreement on the other factors. It is quite evident that each study is unique in itself, mainly induced by the uniqueness of the respondents and their socio-economic circumstances respectively. Prescribing a universalistic approach to determining adoption factors is thus hazardous as it might otherwise be an oversight of the uniqueness of the socio-economic factors of agriculture producing households. Thus there is always a need to highlight these variable socio-economic factors in any study that relates to technology and innovation adoption

6. Conclusion

Alene and Coulibaly (2008), indicate that much of the observed annual growth in agricultural total factor productivity since the 1980s has been attributable to germplasm improvement research that generates modern varieties. Masters *et al.* (1998), and Maredia *et al.* (2000) indicated a 20% to 40% rate of return on individual commodity research investments in the SSA region. However, much of these high returns have not been translated into rapid agricultural growth and poverty reduction. Even though agriculture R & D holds the key to improving agricultural growth, its potentials have not been realized (Alene and Coulibaly, 2008). Furthermore, agriculture R & D has suffered from both ends of the provider and user, where financial and institutional constraints, for instance declining operational budgets and worsening incentives for individual researchers, high staff turnover, and lack of focus on more promising programs, with the research portfolio expanding continually. For the users themselves, in the instance where R & D has generated promising technologies, constraints such as inefficient extension and input supply systems, poor infrastructure and economic disincentives have hindered large-scale adoption and impacts on livelihoods (Alene and Coulibaly, 2008).

Myriad of studies have been undertaken to evaluate contribution of agricultural research and development to improved rural livelihoods. The study identifies that there are some consistencies in reported findings of research and development expenditure having impact on improving agricultural output. Equally so, findings have also been consistent of agricultural productivity increasing at the instigation of research and development as well as the existence of an array of socio-economic factors having major influences on research and development innovation adoption. Despite the existence of spatial as well as temporal variations however, there do appear loopholes within the literature. Expenditure influences on output have appeared aggregated, with few studies, mainly from global research institutes, trying to subdivide how project specific expenditure has tended to influence the specified projects. Furthermore, studies on productivity measures of research and development despite being aggregated, have concentrated on how output has changed vis-à-vis changes in inputs utilised induced by research and development. A short fall however are studies based on the dynamism of the inputs relative to changes in output that they do instigate. Even the socio-economic variables tending to influence research and development output adoption appear to vary from technology to technology, in some instance having a positive influence and in other instances otherwise. Each project is thus unique and no array of diversification of socio-economic variables can be prescribed even though commonality could be identified.

In as much as studies have been undertaken to measure the returns and productivity of research, the results appeared aggregated, with no room for subsector inferences. Furthermore, returns purported by these studies have mainly dwelt on the commercial aspects of agricultural production, with appropriate technical ability and know how. The studies have fell short in addressing how the smaller subsistent players, with limited resources and know how, idealise the new research output. It is therefore imperative that the subsistence aspect be incorporated in evaluating how R&D has impacted on subsistence farm production.

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