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Increasing Agricultural Productivity: A Review of the Multi-dimensional Approach

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Abstract

This article presents a general overview and a reference point for understanding agricultural productivity at farm and sectorial levels. The review covered measures for improving productivity to the extent that it was obvious that incremental growth is a multifaceted interaction of components that relates to technology and technological changes, structural/institutional changes, industry restructuring and resource use and allocation. The ultimate objective of productivity growth is to produce output optimally at the most efficient rate. Productivity is important in distribution of income, the allocation of resources and the relationship between stocks and flows. While firm approach to increase in productivity is important sectoral or national growth approach is more desired.

Keywords: Agricultural productivity; Efficiency; Productivity; Productivity growth; Innovation for productivity; Technical and allocative efficiencies

Introduction

The conceptual study reflects the progress/transformation made by some countries, which must be mirrored or adapted by others to increase total productivity in the agriculture sector. It is expected that the increase will bring about the desired outcome to ending poverty, hunger, under and mal nutrition in the developing countries in particular and the world at large. This study approach followed the Wang and Noe (2010) by adopting a narrative review of the relevant literature rather than a meta-analysis due to the wide variety of disciplines contributing to productivity research and our interest in understanding the different theories and strategies that have been used as the basis for productivity research.

A lot of statistics abound about countries' agriculture. For the developing countries, 75% of the world's poor is noted to live in rural areas and are farmers. Agriculture is the major source of income and employment in Sub Sahara Africa. It accounts for 34% of Gross Domestic Product (GDP) and 64% of the labour force in Sub-Saharan Africa. Poverty alleviation in regions as this is therefore directly linked to agriculture (Jack 2013). Hence agriculture is widely viewed as a powerful tool for reducing global poverty; it is up to 4 times more effective in raising incomes among the very poor than other sectors (World Bank 2013). For agriculture to be successful as a poverty reduction strategy, its productivity growth must be guaranteed.

In agricultural sense, productivity measures how well farmers and agribusiness companies combine inputs to produce output. Growth in productivity reflects increases in the efficiency of the production processes which, in turn, occur as a result of improvements in technology or knowledge. Productivity can also be influenced by policy

decisions of government (Mallawaarachchi et al., 2009) and the non-physical product of innovation, efficiency, management, research, weather, and luck (Ball 2006).

According to Dethier, (2011), the growth of agricultural productivity has stalled. The yields of major grains grow by about 1 percent per year, which is lower than the population growth rate. Expanding the cultivated area is not a possibility to meet future needs, in order to feed the growing population the only solution is increasing agricultural productivity. Increasing productivity that gives a major boost to economic growth and substantially reduce poverty in low-income economies such as Sub-Saharan Africa depends on a range of factors (Dethier 2011; World Bank 2013). Achieving productivity growth relies on the efficiency of combining resources and the support systems available particularly those that motivate the human capital. Motivating the human capital is underpinned by theories some of which are discussed in this study.

Some theories relevant to increasing productivity

Understanding how to increase productivity has been of interest for ages and social scientists particularly psychologists and economists have been actively finding answers to how to raise productivity. Several theories have been formulated, some of which targeted the individual employees/consumers, production systems, process or a combination of any two or more of the target spheres for productivity to be raised. For this study a summary of motivation and formal growth theories will be used to guide the direction of this paper. Several theories exist that can be used to study productivity growth; the Herzberg's 'Two-Factor' theory of motivation, expectancy theory, the three-dimensional theory of attribution and the formal growth theory will be discussed briefly.

Herzberg's 'Two-Factor' theory

According to Herzberg (1959), two factors – motivator and hygiene can lead to satisfaction and dissatisfaction respectively. Though motivator factors increased employee satisfaction and motivation, the absence of these factors do not necessarily cause dissatisfaction. Similarly, the presence of hygiene factors doesn't appear to increase satisfaction and motivation but their absence can cause an increase in dissatisfaction. However de-motivated employees can be slow to respond to changes that are geared towards increasing productivity. Haenisch (2012) study on motivation and productivity reported that workers respond productively when well supported, to effective supervision, open communications, elimination of bureaucracy, a sense of achievement on the job, teamwork, and rewards and recognition. These factors, as acknowledged by management, lead to improvements in overall productivity. Apart from the two factors theory proposed by Herzberg, the expectancy theory is also important to productivity growth study.

Expectancy theory

Expectancy theory (Porter & Lawler, 1968; Vroom, 1964) is a three prong concept composed of 'Valance, Instrumentality and Expectation'. The theory proposed that an individual perceive the likelihood that an effort will lead to performance and that

performance will subsequently lead to the desired outcomes. Moumouni and Streiffeler (2010) in their contribution to the theory explained that expectancy theory presents a motivational force process determined by the three prongs which combine in a multiplicative way. While expectancy is the belief that an individual's effort will result in achieving desired outcome, instrumentality is the belief that if one does meet performance expectations, there will be reward and the value the individual put on the reward is the valance. This theory can be used to express the adoption of innovation and technology.

The importance of technology and innovation cannot be stressed enough in the process of increasing productivity. The adoption of new technology and innovation depends on how well the farmers perceive the benefits. Schnelle et al. (2010) reported a positive correlation between the quantity of goal-relevant resources and the tendency to choose approach to meet the goals, and that change in the availability of resources shifts goal choice. Therefore the underlying mechanism linking resources and goal valence is output expectancy (Wright, 2011) hence individuals will behave depending on the expected outcomes and how the reward is perceived. Another relevant concept is the three-dimensional theory of attribution.

Three-dimensional theory of attribution

Weiner (1971) proposed the 'Three-dimensional theory of attribution' The important assumption of the theory is that an individual is motivated to understand the causal structure of his environment, to know why an event has occurred, and to what source the event can be ascribed. The theory is based on attribution factors such as stability, *locus* of control and controllability. Therefore when motivation factors for productivity growth are stable and the drivers of motivation can be determined either as internal or external factors and are controllable, this will surely will lead to increase in productivity.

Kraus and Gemmill, (1990) suggested that from an attribution perspective, leadership is not a property of leaders, but a causal attribution constructed by observers to explain behaviour or events believed to be representative of leadership. Therefore the theory explains different reactions in terms of situational factors and a leader's cognitive processes. The situational factors can be either internal - lack of effort or external - resources were inadequate. The attribution made by a manager influences a response to a challenge. As a way of encouraging employees to be more productive, they may be praised for following prescribed standard procedure even though the results weren't exactly the expected outcome. This way, employees are encouraged to attribute the deviation to controllable factors, which again, can be improved upon in the future. While the previous theories mentioned above relate to motivating the employees for increased productivity, the formal growth theory encompasses all the factors of production and their enablers.

Formal growth theory

Abramovitz, (1956) growth theory is a seminal published paper that relates to management of productivity. The theory provided for the estimation of the forces that

lead to increase in productivity of labour and capital and that these forces determined at that time approximately half of the historical growth rate of the United States' real gross national product. From the economist perspective, the marginal productivity of capital will be high or low depending on the ratio of capital to other factors, and will diminish as capital grows relative to them. This reflects the "old" neoclassical view of growth theory. However, Abramovitz argues that increases in economic efficiency as the scale of output grows can offset diminishing returns. It is the estimation of the forces of the determinants of productivity that reveals the efficiency that made Abramotitv's work different from old neo-classical theories.

The main theoretical approach to studying productivity is based on 'formal growth theory', where output growth is expressed as a function of growth in inputs and growth in the efficiency with which inputs are transformed into outputs. Different approaches to calculating productivity growth can be used, with the 'neoclassical' model treating growth as exogenous (based on capital accumulation and national savings); and 'new growth theory' incorporating growth as endogenous (through technical change, research and development and capability building activities).

Agricultural productivity

While agriculture is characterised by wastage at the supermarket and household consumption level in the developed countries, ability to produce enough is the bane in the developing world (Mason et al., 2011). One of the major constraints to agriculture in developing countries is inefficiency and; improving it across the agricultural value chain is important to increasing productivity and reducing poverty (Ogbeide & Ele 2015).

Productivity is often confused with increased production. Increased production often time results from an increase in inputs however, productivity is tied to an increase in production due to a more efficient use of inputs or a combination of both of the situations. It is a measure of how efficient the production process is, irrespective of quality or quantity of output, or the quality or quantity of inputs used in the process. It is a relative concept and can only be determined when assessing per unit output derived from per unit inputs in the production process. Therefore to increase productivity issues relating to inefficiency and inadequate support mechanisms must be addressed as increasing agricultural productivity is a panacea to the wellbeing of any countries' economy as a whole (International Food Policy Research Institute – IFPRI 2015).

In simple terms, productivity is measured as a ratio of output to one or more inputs. This indicates productivity will rise when inputs in the production process are optimally utilised to achieve greater levels of output. Olayide and Heady (1982) from an agricultural perspective, noted that the input-output process of farm production is important in at least four major problem areas that include distribution of income, the allocation of resources, the relationship between stocks and flows and the measurement of efficiency or productivity.

A firm approach to productivity is important as it forms the nucleus of the expected growth at the sectoral or national level. It also measures and reflects the actual

productivity growth at the farm level. A sectoral or national approach relates to policies, strategies and innovations, science and technology and farming systems that are directed to enable productivity gains at the farm level with consequent increase in the standard of living and wellbeing of the populace. At this level, total productivity can be aggregated and the contribution of the various support instruments, strategies and organs can be assessed and evaluated. The sectoral approach is more desired to break the bottleneck at the farm or Agribusiness level (International Food Policy Research Institute – IFPRI 2015).

Whether an agricultural activity is efficient or not is normally defined from the outcome of technical and allocative efficiency. Agricultural activity is technically efficient if it obtains maximal output from a set of inputs. Allocative efficiency occurs when a farmer or agribusiness firm chooses the optimal balance of inputs given input prices (Olayide & Heady 1982; Coelli 1995). Nelson (1994) reported that the simplistic approach to determining productivity and its growth is not deep enough, and that a satisfactory theory of growth must encompass the forces behind changes in the immediate determinants such as political, psychological, or sociological factors. Therefore the concept of agricultural productivity is tied closely with the issue of how efficient innovations, resource use and structural changes affect the quality, quantity of production and the wellbeing of the agricultural sector (Australia Government Productivity Commission - AGPC 2009; Coelli 1995).

At a sectoral or national level, assessing productivity growth captures the economy's ability to harness its physical and human resources to generate output and income (AGPC 2009). The theoretical approach traditionally used to study productivity is hinged on "formal growth theory", where output growth is considered dependent on the growth in inputs and the growth in the efficiency of inputs transformation into outputs. The theory has some limitations when it comes to the identification of possible influences on productivity growth.

Certain assumptions are required in formal growth theory to satisfy conditions for logical consistency and equilibrium. These conditions impose some restrictions on the numbers and types of factors that can be readily incorporated into formal models (Productivity Commission 1999). While economists recognise that the level of output is determined by the quantity of factors of production (land, labour and capital) and elements that affect their productivity - the state of the arts, industrial and financial organization, the legal system, etc., economic growth can be understood as a function of changes in or improvements in these 'immediate determinants of output' (Nelson 1994).

The growth in agricultural productivity in Africa and most developing countries mainly results from increase in land applied to farming of crops and livestock. In most of the other parts of the world, agricultural growth comes from intensive rather than extensive growth. Intensification is vital not only to meet increasing demand but also to reduce deforestation, environmental devastation, and global warming (Dethier 2011).

Various approaches have been employed in agriculture to increase productivity including stand-alone and multi-dimensional approaches. The multi-dimensional

approach to agricultural productivity increase involves a wide range of applications of innovation, resources use management and structural changes to the extent guaranteed by incentives spheres such as economic stability and trust, market incentives for investment, capacity building and targeted incentives (OECD 2014). These incentive areas are well favoured to blossom when a stable government exists with sound socio-economic polices that support macro-economic issues - trade and investment, financing, infrastructure, labour, education and innovation. Therefore it can be stated that the quality of governance and policy prescriptions are central to increasing agricultural productivity. It is on this premise that the African Union's New Partnerships for African Development (AU-NEPAD) issued a Comprehensive African Agriculture Development Programme (CAADP) which described a collective vision for agricultural growth with a key component of the vision relating to improving agricultural productivity through enabling and accelerating innovation (FARA 2014).

According to the Organisation for Economic Co-operation and Development - OECD (2014) and O'Mahony (2007), innovation, structural change and access to natural resources are key drivers of productivity growth and sustainable use of resources. Policies that encourage economic stability and trust in institutions, private investment in a transparent and predictable environment, capacity building, including provision of essential public services and targeted incentives for innovation, structural change and sustainable resource use in agricultural systems, impact favourably on productivity (OECD 2014).

Importance of Agricultural productivity growth

As populations get larger, economic growth provides the only sustainable way of improving living standards, which makes increasing productivity an important consideration for national growth (World Bank 2004). A good investment climate drives productivity growth by encouraging investments that bring diverse inputs to production processes to ensure efficient use for optimal output.

Productivity growth unveils success or failure, increase or decrease in efficiency of performance of input variables in metric terms that farmers and the sector have applied to gain output. From firm, industry and national perspective, it relates to how efficient inputs are transformed into output. Increasing productivity enables conservation and better use of natural resource at the farm level. FAO (n.d.) and Carswell (1997) pointed out that farming practices are moving towards intensification that relies on natural biological processes and biodiversity management to increase the productivity of agroecosystems. This is a gradual shift away from interventions in the ecosystem with a lasting carbon footprint, such as soil tillage, heavy dependency on non-renewable inputs and chemical-based intensification. The underpinning scientific and biological principles for improving soil health, managing pollination or controlling pest populations – incorporated in farming practices – show that yields can be increased through the sustainable management of ecosystems (DFAT 2015).

National productivity growth indicates more aggregate outputs per aggregate inputs, which translates to greater returns on total inputs, thus more quality of life for the

citizens. Increased productivity reduces poverty and lower food prices. Agricultural productivity growth can reduce poverty directly, by raising farm incomes, and indirectly, through labour markets and by reducing food prices. The poverty-reducing effect of increasing farm incomes depends on the participation of poor small scale farmers in the growth process. Agricultural growth also reduces poverty by creating employment opportunities for the poor (World Bank 2013). In South Asia and Latin America, 25 percent of the active rural males, usually the poorest, are primarily employed as wage labourers in the agricultural sector. Increasing productivity of staple foods that are non-tradable reduces food prices to poor consumers. In addition to the urban poor, more than half of poor rural households are typically net food buyers benefiting from lower prices (World Bank 2013).

Employment opportunities for farm and non-farm labour are enhanced with increases in productivity with the tendency for strong linkages at business to business level (Dethier 2011). Productivity growth in agriculture can reduce labour input in the production process, however can create other job avenues for the retrenched labour in other related or non-related sectors. Increasing productivity often requires a blend of science, engineering and technology which involves the use of specialists in the various endeavours that must be engaged to drive the engine of productivity growth (International Labour Office 2008).

Mallawaarachchi et al. (2009) noted that historically, farmers in Australia have relied on productivity growth to counter the long-term deterioration in the terms of trade, where input prices have increased at a faster rate than output prices. Since the deterioration in the terms of trade has slowed, recent productivity growth has contributed to real growth in the long-term profitability.

Productivity growth enhances competitiveness. It is argued that competition, whether it comes from other firms at home or from imports, can provide incentives to implement many factors that promote productivity growth such as incentives to adopt latest technologies and to innovate in order to gain some product or price advantage over competitors (Productivity Commission 1999). Therefore competition puts some pressure on farms and related industries to rationalise, retire less productive operations and to modernise. It provides incentives to develop new markets which bring gains from specialisation, economies of scale and the spreading of risks (Dethier 2011; Mallawaarachchi et al., 2009; Productivity Commission 1999).

How to improve Agricultural Productivity

Increasing agricultural productivity is, under normal circumstances, a challenge – today, with global issues such as soaring food and fuel prices, climate change, increased poverty, growing urban population, as well as consideration for environmental sustainability makes the challenge even bigger, particularly for the developing countries with minimal resources and infrastructure to support productivity growth and sustainability (FAO 2015).

In the past, productivity growth was synonymous with job cutting mainly due to the substitution of capital for labour, cost cutting or intensification of work effort (O'Mahony 2007). Concurrently, there has been a greater emphasis on positive aspects and with the growing realisation of the importance of productivity growth comes the need to understand the sources and sector location of changes in outputs in order to increase productivity (Australian Treasury 2009). There is no single prescription as to how to increase agricultural productivity. Several approaches have been recommended (OECD 2014; FAO 2015; FARA 2014). However what is common about how to increase productivity includes better management of natural resources, good agricultural policies, innovation, structural change and communications that ensure technical and allocative efficiencies. The framework below will help to create an understanding of how to increase agricultural productivity. the realisation that, by investing and learning to do things better, society as a whole benefits. This change in attitude accelerated productivity growth and is linked to the introduction and use of information and other technologies (O'Mahony 2007).

Agricultural productivity framework

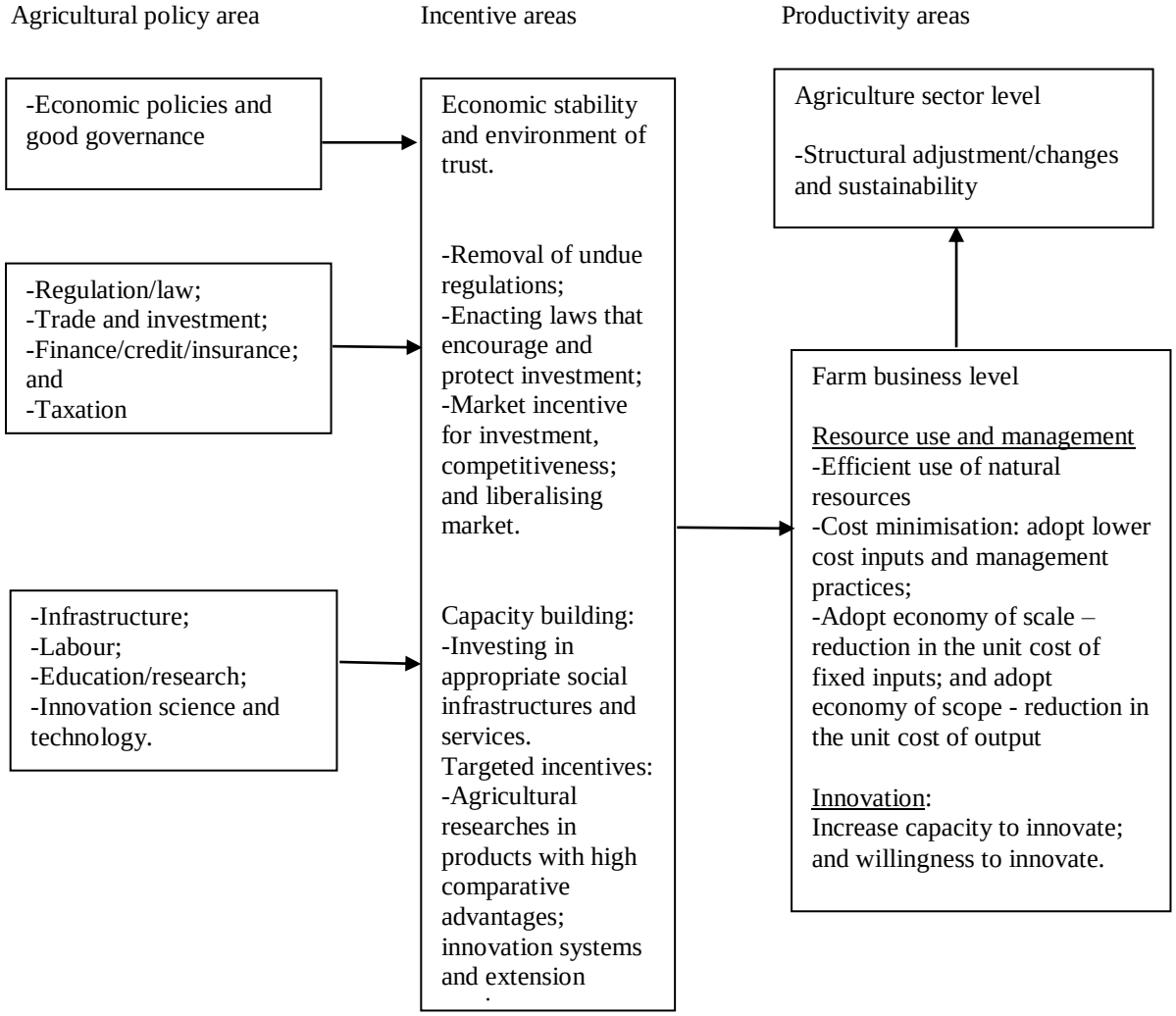

Figure 1 Agricultural productivity framework. Adapted from ABARES (2014) and OECD (2014).

Productivity can be private sector driven and achieved; it is the duty of the government to set the policies that encourage private sector farms and allied businesses to be imaginative and creative in ways that enable efficient production systems and methods that guarantee increase in productivity.

Good agricultural policies and institutions for productivity

Policy direction and policy stability are considered important in creating conditions conducive for increasing productivity. Productivity Commission (1999) noted that government policies can increase the emphasis given to economic objectives, as well as assist in developing capabilities in education and training; and science and innovation which promote productivity growth. Arguably the more stable good government policies are the better they create a more certain Agribusiness environment in which to make long-term investment decisions that promote productivity growth.

Government policies that guarantee productivity must be able to create access to production assets by including the disadvantaged or excluded groups, such as women and ethnic minorities. Access to land, water and human capital are determinants of the ability of households to participate in agricultural markets, secure livelihoods in smallholder farming environments, compete as entrepreneurs in the rural industry economy, and find employment in skilled occupations. Government policies must be framed and implemented in a way that enhance access to assets through significant public investments or incentivise more private sector investment in irrigation, health, and education. Increasing access may also call for affirmative action to equalize chances for disadvantaged or excluded groups (World Bank 2013).

The Organisation for Economic Co-operation and Development – OECD (2014) reported a strong relationship between policies and productivity and sustainability outcomes and that innovation, structural change and access to natural resources are key drivers of productivity growth and sustainable use of resources. However, policies affect these drivers through four main incentive areas:

- Economic stability and trust in institutions (justice, security, property rights) which are essential to attract long-term investment into the economy;
- Private investment, which in turn requires a transparent and predictable environment that balances the interests of investors and society;
- Capacity building, including provision of essential public services; and
- Targeted incentives for innovation, structural change and sustainable resource use in the food and agricultural system (OECD 2014).

Government policies must support agricultural productivity through building of adaptive capacity for institutions and individuals in agriculture to adapt to changing circumstances, improve human capital, institutional support and technology that are acquired from both national and global sources (Mallawaarachchi et al., 2009; OECD, 2014; O'Mahony, 2007). Furthermore, Mallawaarachchi et al. (2009) argued that the usefulness of a given technology may be affected by regional differences in environment and natural resource availability. Therefore capitalising on regional knowledge and technology spillovers may provide new technologies at a lower cost; however, it also

requires local research capacity to comprehensively address local adoption issues and ensure new technologies are customised to local conditions.

A policy that results in openness of an economy to trade and investment, from a theoretical and empirical point of view is considered to be potentially a major influence on productivity determinants. Katz (1998) compared open and closed economies and noted that of 11 open and poor economies in 1970, 8 (72.7% of the sampled countries) were not poor in 1989. On the other hand, of 24 closed and poor economies in 1970, 21 (87.5% of the sampled countries) were still poor in 1989. Despite the competitive element associated with open market it provides opportunities for:

- Inward direct foreign investment that brings with it technology, production methods and human expertise;
- Imports of final products, intermediate goods and capital equipment can have technology embodied within them that would not otherwise be available;
- Intra-industry trade leads to specialisation between countries in production of goods and services to which they are better suited and more productive; and
- Development of foreign markets through trade and outward foreign investment can provide access to ideas and trends, can increase the volume of sales that assist exploitation of economies of scale (Productivity commission 1999).

Ergas and Wright (1994) reported the benefits of good trade policy stating that a positive relationship exists between trade liberalisation and the performance of Australian firms. They suggested the benefits were a function of:

- International exposure that encouraged greater learning as Australian firms come into contact with and measure themselves against a broader range of rivals, focus on improving quality and customer satisfaction and learn from customers and suppliers;
- The greater pressure to tackle inherited inefficiencies such as constraining industrial relations arrangements; and
- Greater selection between firms, as weaker firms are forced to adjust or decline.

A good policy, beyond investments in infrastructure, innovations including commodity exchanges, market information systems and market-based risk management tools, reduces transaction costs and risks in food staples markets (World Bank 2013).

Hence it was the view of Productivity Commission (1999) that good policies and institutions are required to increase agricultural productivity. Institutions govern the way in which human and economic interaction takes place and affect performance by governing interactions between governments, firms and individuals thereby impacting the costs of obtaining coordination and cooperation in economic activities. Institutions affect, amongst other things, the costs of production and exchange and shape incentives to be productive. Some illustrative examples of institutions are corporations' regulatory bodies that provide for governance, behavioural and disclosure requirements, wage-determination systems, science, technology and innovation systems and education and training systems (Productivity Commission 1999).

Research, development and extension for productivity

Building research capacity particularly in Africa is essential to productivity growth both in terms of training researchers and infrastructure development - laboratories and equipment. Governments must invest in the scientific skills pipeline from school education through to research at university level (PACN 2012). Investment in education guarantees the provision of the requisite manpower categories required to drive productivity. Even so DAFFF (2013) noted that the social and economic returns on agricultural research, development and extension (RD&E) investment are consistently high and correlate closely with increased productivity and low food prices.

Marslen (2014) pointed out that agricultural research and development levels have declined over recent decades due to the gradual shift in the international agricultural market, from centrally-organised rural industries to privatisation. Marslen emphasised that in developed countries such as Australia, huge increases in private sector investment are evident in the agricultural research industry and while this is good for the industry, it has come at the cost of a reduction in public investment.

Extension services are an important mechanism to communicate new technologies and practices to farmers, and must go hand-in-hand with research and development (R&D). Non-governmental organisations that have active links with both small scale farmers and researchers have an important role in facilitating this. The existing programmes should examine current situations to identify areas where R&D can contribute knowledge to help ensure that technologies for agriculture reach those who need them (Pan Africa Chemistry Network –PACN 2012). From a benefit perspective, this will allow countries to build their research capacity and establish the correct sequence of long-term scientific advice for extension services.

A well-directed RD&E leads to improvements in productivity through lowering the costs of production, increasing yields, improving sustainability, encouraging efficient resource allocation and providing opportunities to enter new markets. RD&E is also critical in preventing and responding to emergent pest and disease incursions that have the potential to harm agricultural production. It is crucial that innovation occurs along supply chains as a key enabler of productivity growth (Woods 2009; Department of Agriculture, Fisheries and Forestry - DAFFF 2013).

DAFFF (2013) identified four key pathways to grow productivity in the agriculture sector, which are underpinned by RD&E strategies that include resource availability, productivity, market and production cost. When considering RD&E strategies that are able to secure and increase resource availability, they must be able to develop new whole-farm production systems for existing and new agricultural areas, develop cost-effective ways to build resilience to seasonal changes and foster adaptation opportunities. It must develop and promote best management practices that maximise resource use efficiency and availability (DAFFF 2013; Barrett 2008; Woods 2009).

Research, development and extension strategies for supply/value chain productivity growth must include enhancing science and technology capability, including

partnerships with universities, to provide problem solving research that boosts productivity, increase the uptake of best practice and increase the value of harvested product through improved varietal attributes and/or post-harvest processing and packaging (DAFFF 2013). Importantly, RD&E must become more collaborative, specialised, have larger critical mass and be less fragmented geographically (Australia Department of Agriculture 2015).

Woods (2009) and DAFFF (2013) noted that agricultural research facilitates productivity through incremental increases in the biological potential of yield. For example, changing crop architecture to increase the harvest index and the proportion of the biomass of the product and increasing the efficiency of water use. Wood described the substantial increases in the yields of marketable product per mega litre of water for both rice and cotton as an efficiency/productivity success story. In aquaculture, scientists have used their biological knowledge of prawn to select more rapidly growing and early maturing ones from naturally occurring populations.

According to Barrett (2008), market participation influences productivity and is vital to economic growth and poverty reduction. The result is that it leads to market-oriented production. While market participation is associated with generating farm surplus, local market conditions can also provide incentives to increase productivity. In integrated markets the returns to increased production decrease less rapidly when compared to isolated markets. Moreover, poor infrastructure and weak institutions raise transaction costs that considerably alter production, productivity and market participation decisions (Rios, Shively & Masters 2009). As a result, increasing rates of market participation and productivity could have two-way synergies, and increasing both could boost living standards.

Therefore market targeted RD&E strategies must focus on securing and increasing market access and participation through identification of new market opportunities and processes to add value suitable for new and established markets, improving food quality and delivering fresh, safe products with minimal pesticide residues through efficient supply chains to consumers (DAFFF 2013). While the cost of production is an important determinant of productivity, RD&E plays a vital role in productivity growth by lowering cost profile. When genetics of crops and livestock are improved for increased yield and resilience to biotic and abiotic stresses, when enhanced capabilities, diagnostics and tools for surveillance, detection and control of pests and diseases are available, and when improved systems for integrating new technologies, focusing on people, enterprises and business management to support adoption and uptake of new innovation are provided, production cost is minimised and product price will be lower (DAFFF 2013).

Links between productivity and R&D are strong, and they contribute to collective industry level outcomes and specific practices generating private economic benefits (Mallawaarachchi et al., 2009). The lag time between investment in research and tangible productivity gains, means that a long-term investment approach is required. Private investment in R&D tends to be short-sighted and commodity focussed and as such

mimicking a long-term public R&D policy and plan is required if private investment is to be effective in the long run (Wood 2009; Mallawaarachchi et al., 2009).

Increasing productivity involves transformative steps to create new products, new industries and new markets for agricultural production. It is imperative that agricultural scientists must connect with other specialist disciplines such as nutrition, consumer psychology and other behavioural sciences to address issues such as major global human health problems caused by nutrient deficiencies. Working in partnerships with these disciplines, researchers are able to increase essential nutrient levels in food and remove some allergy causing agents from staple foods (Woods 2009). Techniques to efficiently extract waste materials from agribusiness processing for conversion to new products for energy and pharmaceutical uses are being developed in partnership with chemical and environmental engineers. Agricultural scientists are working with the spatial sciences to improve the ability to assess soil production potential by looking into the soil profile using satellite remote sensing. This will enable industry to better identify areas of risk and opportunity as climate change progressively shifts productive land suitability (Woods 2009).

Farm management of natural resources for increased productivity

FAO (2015) noted that to increase agricultural productivity involves better use and management of natural resources especially agricultural biodiversity resources that include but are not limited to seeds, pollination and beneficial fauna. Biodiversity enables attainment of higher yields while promoting the sustainability of the farming systems and concurrently progressing from subsistence farming to market-driven agriculture. In this regard, the market driven outcome is consequent upon biological efficiency of the production system (FAO 2015).

Moisture availability is an important condition for crops and livestock farming. The distribution of moisture naturally is not even, it can range from inadequate rain fall amount to drought in many areas (Kokic 2006). International Centre for Trade and Sustainable Development - ICTSD (2008) noted that access to water remains a great challenge particularly in Africa. Overall, it is estimated that only four percent of the total agricultural land in Africa is irrigated, the remaining parts being rain-fed, therefore are subject to climate and rain variability. Considering the situation, it is important to understand and apply the best cropping practices that maximise water efficiency to improve the factor productivity.

Quality soil endowment is relative and varies geographically such that it contributes towards determining agricultural productivity. Soil use and management can be vital to output outcome and the use of chemical technologies can be helpful to increase agricultural productivity. Access to these technologies is limited particularly in Africa and most developing countries such that farmers are not able to take advantage of them (Pan Africa Chemistry Network – PACN 2012; Kirkegaard & Hunt 2010).

Soil structure and chemical fertility are vital to crop growth and increase in productivity. The capacity of soil to capture, store, and supply water to crops is

influenced by its long-term management (Kirkegaard & Hunt 2010; Hatfield *et al.*, 2001). Foley and Silburn (2002) and Kirkegaard and Hunt (2010) noted that to maintain the soil structure for maximum productivity, the need arises to minimise excessive cultivation, minimise the effects of compaction agents such as heavy machinery or livestock, retain surface residues to protect the soil from wind and rain impacts and also to maintain adequate soil organic matter.

Similarly Zhang et al. (2007) and Chan and Pratley (1998) reported that light textured and hard-setting soils with inherently low organic matter can be particularly susceptible to surface crusting, compaction, and structural decline. Therefore soil can be said to be fragile, and easily damaged, and sustaining its productive capacity may require farmers to change their farming practices. Poor soil usage leads to depletion of soil quality and nutrients and is known to reduce crop yields. PACN (2012) noted that a reduced crop yield will, in turn, result in reduced soil cover, leaving the soil exposed and open to the effects of weathering and accelerating the process of soil erosion.

However, the application of ameliorants such as gypsum or periods of pasture ley to increase subsoil macroporosity can improve water infiltration and storage and crop performance on some soils. (Kirkegaard & Hunt 2010; McCallum et al., 2004; Hamza & Anderson, 2005; Chan et al., 2006). The use of manures and other organic fertilisers can help to increase organic matter in soils. The use may not be practical for some smallholders because they are often unable to farm both livestock and crops due to land constraints and it can be labour-intensive too. Furthermore, organic manure contains insufficient inorganic nutrients to meet the needs of crops (Hamza & Anderson, 2005; Chan et al., 2006; PACN 2012). The application of greater amounts of inorganic fertiliser helps to address deficiencies in two key nutrients, nitrogen and phosphorus and improve productivity. (PACN 2012; McCallum et al., 2004; Hamza & Anderson, 2005).

Farm size is an important component of agricultural productivity. For many developing countries, agriculture is at a subsistence level with the characteristic land fragmentation that denies economy of large scale (Robson 2012; World Bank 2013). Despite the subsistence agriculture providing the livelihood for the rural people, productivity cannot be maximised (Livingston, Schonberger & Delaney 2011). Large farm size encourages mechanisation and use of modern technology to increase efficiency. According to Australian Bureau of Agricultural and Resource Economics –ABARE (2004), an analysis of Australia dairy farms shows farms with larger herd size produced on average higher quantity of milk and were more labour efficient. The study also showed that the fixed cost and total cost per litre of milk produced were lower on average for farms with larger herd size than the small ones.

The effective governance and use of land are important to productivity growth, job creation, food security, disaster risk management and mitigating the impact of climate change. Good land governance that guarantee secured land tenure encourages responsible large scale private investment and makes rural communities stronger, improves rural infrastructure and living conditions and boosts investment in and efficiency of smallholder agriculture (World Bank 2013).

Innovation and technology for agricultural productivity

Productivity is critical to sustainability; it is an improved efficiency that underpins any sectors' ability to compete both at local and international level. Only viable and productive sectors that can support the science needed to understand how best to use less resource and leave a smaller carbon footprint for each unit of production will become relevant into the future (Woods 2009). Science improves productivity by first addressing the causes of inefficiencies in production systems that hinder biological yield from reaching potential.

At farm-level, productivity growth is attained as farmers reduce their production cost by adopting more efficient technologies and management practices which in turn allows them to compete locally and internationally. The Australian Bureau of Agricultural and Resource Economics and Sciences - ABARES, (2014) reported that as the relative prices of farm inputs change over time, profit-maximising/cost-minimising farmers opt for lower-cost input combinations. This practice gives rise to substitution and income effects which, in the latter case, contribute to productivity growth from input saving. While some farmers may choose to produce the same output with fewer inputs, others may increase inputs and production in some instances, through expanding farm size to further exploit the benefits from increasing returns to scale (ABARES 2014; Sheng et al. 2014).

Cost minimisation is usually adopted using several innovation strategies including the use of Information technologies (IT). Tamer (2013) noted that mobile phone and other IT systems have the ability to make a huge impact on farm cost. Smart power systems, precision agriculture tools, farm management software, and affordable sensors and mobile phone are some of the innovations that drive the increase in productivity.

In the agricultural value chain, the productive engagement of the functional units in the value chain, and how the information around these units is managed, are important to productivity growth. One way to improve the efficiency in the information flow is the use of mobile phone technology (Halewood & Surya 2012; Ogbeide & Ele 2015). While mobile phone technology application in the agricultural supply/value chain in developed countries can be taken for granted, the same cannot be said for Sub-Sahara Africa and many other developing countries. Mobile phone provides various opportunities to acquire and transfer knowledge and information among players in the value or supply chain including the government (Aker & Mbiti 2010; Ogbeide & Ele 2015).

Productivity can be hampered by lack of access and lack of timely access. Ogbeide and Ele (2015) reported that effectively and efficiently obtained market information provide benefits to farmers, input suppliers and consumers. When farmers have up-to-date market information; they are able to negotiate better terms with other stakeholders. From sales' perspective, the increased use of mobile phone for market information facilitates spatial distribution of products from production areas to consumer market with clear price signals from consumers market to farmers. With this information farmers are able to adjust product quantity, quality and variety as required according to

the target markets (FAO 1997; Ogbeide & Ele 2015; Szilagyi & Herdon 2006; Lio & Liu 2006).

Considering the enormity of the effort to obtain market information across a vast geographical spread, mobile phone technology has been widely deployed by farmers to ensure they are up to date. Farmers increase their market intelligence via mobile phones and are able to analyse historical and current market information to make production decisions, such that relate to what and when to plant or breed, at what stage should harvesting be done and where market production should be directed (Szilagyi & Herdon 2006; Ogbeide & Ele 2015). Mobile phone benefits extend beyond enabling farmers to socially interact with family members and their peers; the technology enables them to access market information quicker and efficiently, thereby saving travel/transportation time and cost. The same is true when farmers use mobile phone for financial transactions and are able to obtain their transaction details without the need to visit the banks (Aker & Mbiti, 2010; Ogbeide & Ele 2015). These benefits help farmers to improve their productivity.

Modern biotechnology has the potential to speed up the development and deployment of improved crops and animals. FAO (n.d.) reported that marker-assisted selection increases the efficiency of conventional plant breeding by allowing rapid, laboratory-based analysis of thousands of individuals without the need to grow plants to maturity in the field. The techniques of tissue culture allow the rapid multiplication of clean planting materials of vegetatively propagated species for distribution to farmers (FAO n.d.; Quain et al. 2015). Genetic engineering or modification - manipulating an organism's genome by introducing or eliminating specific genes - helps transfer desired traits between plants more quickly and accurately than is possible in conventional breeding. Animal biotechnologies, in similar way to plants, are tools used in genetic manipulation. Scientists and animal breeders use biotechnology to produce healthier animals, make breeding easier and to produce carcass with high “kill out percentage” and better quality at slaughter. Animal breeders therefore improve the breeding process through techniques like artificial insemination, cloning and genetic engineering (Animal Smart n.d).

As agriculture is faced with the vagaries of nature, importantly the menace of pests and pathogens that also pose a significant risk to improving productivity. The concept of biosecurity - where the protection of farmers’ crops and/or livestock and the entire industry from the entry, establishment and impact of exotic pests - is indispensable (Cotton Research and Development Corporation –CRDC 2012). Building a strong biosecurity capability will reduce crop failure and food losses, enable access to international markets, help to address the spread of exotic pests and diseases and reduce chemical input use (DFAT 2015). CRDC (2012) noted that an effective biosecurity can keep Australia free from many of the pests that affect plant industries overseas, and also increase sustainability and production efficiency. In addition, biosecurity practices can limit the effect of endemic pests through maintaining area freedom or minimising their impacts and spread.

Genetic engineering is another useful tool in animal production. Genetic engineering introduces new genes to the food animal population. Animal breeders are interested in using this technology to increase animal productivity, improve resistance to diseases and parasites, and make food more nutritious. Precision agriculture increase productivity. European Fertilizer Manufacturers Association – EFMA (2006) reported that remote sensing of crops for colour intensity enables determination of the nutrients need of crops. Farmers therefore apply varyingly the appropriate amount of fertilizer according to the nutrient status of the various soil pattern that made up the farm land. It is argued that innovation such as this will allow for a more uniform crop yield and more efficient use of fertilizer. Remote sensing and Soil testing - particularly for pH, P, K and Mg - when performed routinely assist in fertilizer input and any necessary adjustments according to soil status and crop needs. (EFMA 2006).

Despite the presence of innovation strategies, agricultural productivity is improved upon only to the extent to which farmers make use of existing innovations and technologies. The adoption of technologies by farmers is influenced by a range of factors that determine risks and returns. They include market conditions, suitability as evident from available information, as well as personal attributes such as the education, experience and expertise of individual farmers. Productivity growth will be higher where the rate of adoption and the diffusion of new technologies by farmers and farm businesses is rapid (Ogbeide & Ele 2015; Mallawaarachchi et al., 2009; Martin & Abbott 2011; Productivity Commission 1999).

Conclusion

Productivity is not equivalent to output (or production). Productivity reflects improvements in the ability to transform inputs into outputs in the most efficient manner. In the most literal sense, it is a residual measure of the contribution to output growth after all other factors have been accounted for. The amount by which these input factors combine, their interrelational dependency and their availability determine the productivity. Institutional and structural changes, the role of science, engineering and technology, the availability and amount of natural endowment and, without a doubt, luck are critical to increasing agricultural productivity.

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