

## **TECHNOLOGY CAPABILITIES AND HOW THEY CAN INFLUENCE ECONOMIC *CATCH UP* FOR AFRICAN AGRICULTURAL ECONOMIES**

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### **ABSTRACT**

Strengthening technology transfer mechanisms could help emerging economies especially for the African continent achieve meaningful economic progress that would eventually lead to economic *catch-up*. However technology diffusion in the continent in key sectors like agriculture, health, education and energy has been hampered over the years. This has been due to inadequate infrastructures and the human resource capabilities. Given the fact that Africa only contributes 2% of the total global R&D, positioning the continent to the technology and innovation frontiers for sustained economic efficiency is quite challenging. The article explores the various types of technology capabilities and how they can be natured and diffused in agricultural sector for improved agricultural production as well as the various actors that could potentially drive the diffusion process.

**Keywords:** Technology, agriculture, rural economies.

### **INTRODUCTION**

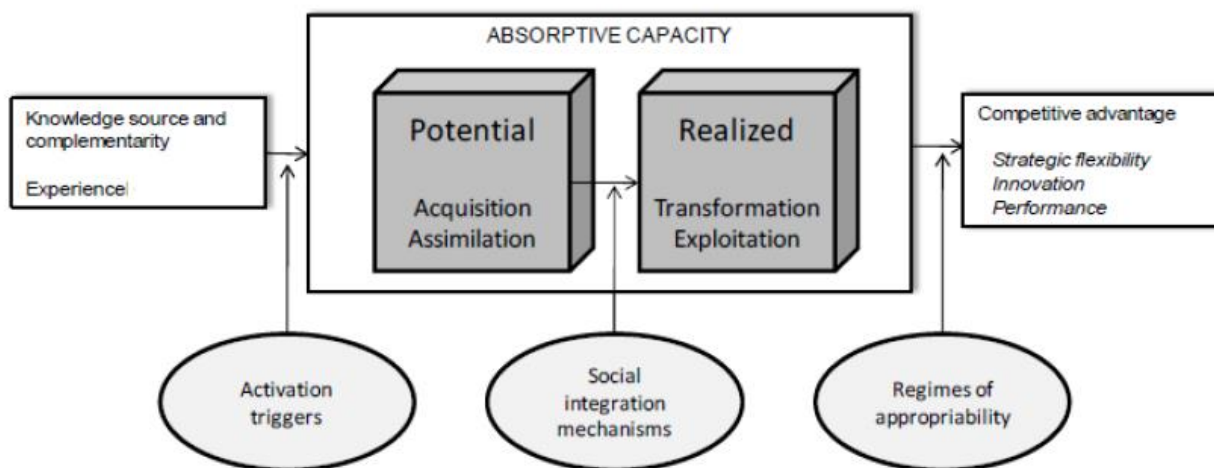
Over the years the emerging markets have failed to catch up with developed countries partly because of technology capability gaps between the two. Emerging economies appear to be laggards as far as innovation technology is concerned thus making it hard to develop competitive economies. Majority of these economies are agro based with little or no value addition to the agricultural produce. Inadequate technology penetration in key sectors like agriculture makes these countries perform relatively poorly globally. To achieve relative competitiveness in agricultural sector, there must be deliberate efforts to develop various forms of technology capabilities. These includes absorptive capabilities, innovative capabilities, and access to complimentary assets. However there must adequate framework conditions like legal frameworks, education and financial support systems that would ultimately sustain the technology transfer process. The author now discusses each of them below.

#### **1. Absorptive capabilities**

These are the abilities for the farmers to acquire, internalise and utilize the knowledge developed outside their networks to help them become more efficient<sup>1</sup>. Absorptive capabilities also means the ability of farmers to identify and assimilate new knowledge from the environment as pointed out by Cohen and Levinthal, 1989<sup>2</sup>.

The three major components of absorptive capabilities are the ability to recognise the value of external knowledge, assimilate it and use it for new economic gains<sup>3</sup>. Zahra and George in 2002 further argued that the farmer must be able to transform the acquired knowledge to meet his or her specific needs<sup>4</sup>.

The figure below by Zahra and George shows a model of how absorptive capabilities can be developed by firms.



**Figure 1: Model of absorptive capability by Zahra and George (2002) Source; Lawer,C,(2010).**

<sup>1</sup> Narula,R,2004. Understanding Absorptive Capacities in an “Innovation Systems” Context: Consequences for Economic and Employment Growth. DRUID Working Paper No 04-02,Oslo Norway.

<sup>2</sup> Cohen, W.M. and D.A. Levinthal (1989), Innovation and Learning: The two faces of R&D, Economic Journal99 (397), 569-596.

<sup>3</sup> Van Den Bosch, F.A.J., R. Van Wijk and H.W. Volberda (2003), Absorptive Ca-pacity: Antecedents, Models, and Outcomes., Blackwell Handbook of Or-ganizational Learning & Knowledge Management, 278-301.

<sup>4</sup> Zahra, S.A. and G. George (2002), Absorptive capacity: a review and reconceptualization, and extension., Academy of Management Review27 (2), 185-203.

This model is a modification of an earlier model proposed by Cohen and Levinthal (1989, 1990). Zahra and George categorised absorptive capabilities into potential and realised capabilities. Potential capabilities include the ability to acquire and assimilate new knowledge while the realised capabilities comprise of the ability to transform and exploit the new knowledge.

They also included in the model the activation triggers and social integration mechanisms as the intrinsic processes that facilitate knowledge flow within the organisation. The two combined with regimes of appropriability produce a resilient and highly competitive system which can be adapted in any agricultural setup.

Farmers' ability to build absorptive capabilities are determined by the following factors

### **R&D investments**

Cohen and Levinthal in 1989 underscored the important role of R&D in building absorptive capabilities for firms. They pointed out that R&D not only helps in generating new knowledge and innovations but also builds the capacity by which these firms can accumulate knowledge.

Other scholars like Becker and Peters in 2000 and Veugelers in 1997 also emphasized on the importance of R&D in building absorptive capabilities of firms. Incentive systems from financial sector including banks and microfinance institutions play an important role in providing funds needed for basic and applied research. The government as well should provide funds to research institutions as well as provide incentive schemes to attract researchers in specific agricultural fields which have got relative significance to agricultural sector.

Farmers' related knowledge and skills

Cohen and Levinthal in 1990, asserted that absorptive capabilities are path dependent and that the easiness to apply any technology depends on an individual's past experience and knowledge. The knowledge is cumulative in nature and as such a great determinant of absorptive capabilities. The more the farmers are trained and educated the more they become responsive to taking up new technologies<sup>5</sup>.

Rothwell and Dodgson in 1991, also found out that farmers need well educated technicians, engineers and technological specialists to help them access knowledge from outside their networks<sup>6</sup>. At this point the support of "gatekeepers" becomes essential. These are the people

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<sup>5</sup> Narula, 2004

<sup>6</sup> Rothwell, R. and M. Dodgson. (1991), External linkages and innovation in small and medium-sized enterprises, *R&D Management* 21, 125-137.

who create the medium or language that can be understood by all players in the innovation process.

They help improve absorptive capabilities through knowledge sharing<sup>7</sup>. The gatekeepers screens the new knowledge and transforms into away that can be synthesized and absorbed by firms<sup>8</sup>.

### **Organisation structure and human resources**

The absorptive capabilities of any farming organisation depend on its ability to stimulate and organise for the transfer of knowledge<sup>9</sup>. It's also the firm's ability to stimulate and share knowledge<sup>10</sup>. Organisational culture that provides incentives for knowledge diffusion has a strong influence on its absorptive capabilities<sup>11</sup>. Close farmer networks and relationships can be good channels in which tacit knowledge is shared and diffused in farmer organisation<sup>12</sup>. Frontier farmers have to take the initiative to share and provide knowledge in order to build up absorptive capabilities for other smallholder farmers<sup>13</sup>. This can be done through agricultural exhibitions and other farmer oriented learning forums.

Absorptive capabilities also include the farmers' ability to integrate existing resources and technology innovations<sup>14</sup>. At this point, its worth to note that absorption does not necessarily mean imitations but firms must be ready to invest into their own capacity to innovate if they have to from outside knowledge<sup>15</sup>. Technologies are highly tacit and without existing innovation structures absorption of the very technologies may be elusive.

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<sup>7</sup> Vinding, A.L. (2000), Absorptive Capacity and Innovation performance: A human capital approach., Department of Business Studies-DRUID/IKE Group, Aalborg University, Denmark.

<sup>8</sup> Gradwell, T. (2003), Outsourcing knowledge creation: don't give the game away., Specialty Chemicals23 (8), 24-25.

<sup>9</sup> Cohen, 1989

<sup>10</sup> Van Den Bosch, F.A.J., H.W. Volberda and M. De Boer (1999), Coevolution of Firm Absorptive Capacity and Knowledge Environment: Organizational Forms and Combinative Capabilities. , Organization Science: A Journal of the Institute of Management Sciences 10 (5), 551-568.

<sup>11</sup> Daghfous, A. (2004), Absorptive Capacity and the Implementation of Knowledge-Intensive Best Practices, SAM Advanced Management Journal (1984)69 (2), 21-27.

<sup>12</sup> Gradwell,2003

<sup>13</sup> Lenox, M. and A. King (2004), Prospects for developing absorptive capacity through internal information provision., Strategic Management Journal25 (4), 331-345.

<sup>14</sup> Narula,2004 p6

<sup>15</sup> Narula,2004 p7

Absorptive capabilities of any firm squarely depend on the available knowledge base. This knowledge comes from both internal and external sources. For the knowledge spillovers to be absorbed effectively farmers must have appropriate absorptive capacity and the external knowledge must be congruent to the farmers needs. As indicated earlier R&D activities and training programs provides the basis for building absorptive capacities for any organisation. Well-trained farmers easily internalises spillovers efficiently. In addition, availability of both basic and intermediary support infrastructure is quite useful for building absorptive capabilities. Basic infrastructure may include electricity, communication, health services and basic education. The other intermediary infrastructure includes actors like Universities and Research institutions which conducts both applied and basic researches as well as generating skilled personnel<sup>16</sup>. The accumulation of higher knowledge can result to higher productivity for farmers.

### **Building absorptive capabilities.**

Investment into R&D activities provides a firm foundation for building absorptive capabilities. R&D enables firms to identify, learn and utilize new knowledge<sup>17</sup>. It also provides the basis for which firms innovate new knowledge. Kodama 1995 and Kim 1997 puts that investments into R&D supports research projects which enhances learning by doing and by doing so firms are able to acquire new external knowledge<sup>18,19</sup>.

Another way of building absorptive capabilities is through investment into human capital. Highly educated farmers mean high absorptive capabilities.<sup>20</sup> Proper training and acquisition of external experts who are knowledgeable can create a pool of knowledge base necessary for developing robust absorption capabilities. Allen in 1977 asserted that firms that carry out their own R&D have wide knowledge base and are highly likely to make use of external knowledge<sup>21</sup>. In addition these firms are better adapted to tap the external knowledge since they can efficiently establish

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<sup>16</sup> Rasiah, R. (2002). "Infrastructure and domestic patents in developing Asia", mimeo, UNU/INTECH, Maastricht.

<sup>17</sup> Cohen, Wesley M. and Daniel A. Levinthal (1990), Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly* 35, 128–52.

<sup>18</sup> Kodama, Fumio (1995), *Emerging patterns of innovation: Sources of Japan's technological edge*, Boston: Harvard Business School Press.

<sup>19</sup> Kim, Linsu (1997), *Imitation to innovation: The dynamics of Korea's technological learning*, Boston: Harvard Business Press.

<sup>20</sup> Cohen, Wesley M. and Daniel A. Levinthal (1990), Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly* 35, 128–52.

<sup>21</sup> Allen, Thomas J. (1977), *Managing the flow of technology*, Cambridge: M.I.T. Press.

internal capabilities<sup>22</sup>. Firms that do not invest in scientific research have less technological opportunities compared to those that invest into R&D<sup>23</sup>.

Prior knowledge and ability to learn new knowledge are a prerequisite to building absorptive capabilities. The learning must be active i.e. learning by doing to enhance knowledge absorption. Technology scouting is one of the ways in which knowledge can be acquired. This involves proactive search of knowledge and communicating the knowledge scouted for brainstorming and subsequent integration. The integration process maybe much more effective when face to face communication is used.

Face to face communication creates stronger networks and links between different actors thus sustaining continuous establishment of resilient absorptive capabilities<sup>24</sup>. Hyundai for example became one of the most dynamic automobile in emerging markets as a result of harnessing and learning new external knowledge<sup>25</sup>.

## **2. Capability to access Complementary assets**

Complementary assets are assets that required to fully commercialise an innovation. They maybe generic, specialized or co specialized assets<sup>26</sup>. Increasing the access of farmers to these assets may make them more competitive because they will harness the full benefits of certain innovations. But this is always not the case since most of these assets are protected by intellectual property rights. Specialized and co specialized assets are idiosyncratic to the innovation and cannot easily be bought on the market hence accrues competitive advantage only to the owner. The owners of such assets tend to protect them from imitations through intellectual property rights and complex internal routines. The tacit nature of such assets also hinders free diffusion of innovations associated to such assets. Examples of such assets include licensing agreements, strategic alliances, marketing capabilities and distribution channels. According to the Teece model, tightly held assets, which have low immitability, fetch more profits from an innovation.

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<sup>22</sup> Becker, Wolfgang and Jürgen Peters (2000), *Technological opportunities, absorptive capacities, and innovation*, Universität Augsburg: Institute for Economics.

<sup>23</sup> Malerba, Franco and Salvatore Torrisi (1992), Internal capabilities and external networks in innovative activities. Evidence from the software industry, *Economies of innovation and new Technology* 2, 49–71.

<sup>24</sup> Duchek, S, (2013), Capturing Absorptive Capacity: A Critical Review and Future Prospects

<sup>25</sup> Kim, Linsu (1998), Crisis construction and organizational learning: Capability building in catching-up at Hyundai Motor, *Organization Science* 9, 506–21.

<sup>26</sup> Arora, A. and Ceccagnoli, M. 2006. Patent protection, complementary assets, and firms' incentives for technology licensing. *Management Science* 52, 293-308.

If the assets are highly held, the owner may choose to negotiate and share the assets through licensing and decide on profit sharing schemes<sup>27</sup>. Access to complementary assets squarely depends on the intellectual property rights of any geographical area. These rights provide guidelines on how knowledge developed elsewhere, can be accessed and taped. Rodger in 2003 asserted that smallholder farmers in emerging markets are unable to “catch up” with their counter parts in the developed countries because they are unable to absorb the technologies already available<sup>28</sup>. These technology assets can be accumulated through continuous imitations sometimes referred to as “reverse engineering”. However due to strong intellectual property rights, the diffusion of these technologies is hindered<sup>29</sup>. Building up stock for complementary assets can be done through foreign direct investments (FDI's), importation and acquisition of foreign licenses to use certain innovations<sup>30</sup>.

### **Building access to complementary assets**

A well-established legal framework to guide the licensing, acquisition and conferment of rights to use the innovation is essential in building access to complementary assets. Research institutions are important in this process as they provide the knowledge base to sustain the survival and subsequent diffusion of the innovations. Financial institutions, venture capitalists and the government are important actors in R&D projects as they provide the necessary funding of these projects. In areas where absorptive capabilities are high, strong intellectual property rights can help stimulate R&D investments thus promoting local innovations. It's a bit tricky to establish whether strong or weak intellectual property rights are fit for smallholder farmers in emerging markets. But in overall the owners of these rights should not make them so exclusive to keep out smallholder farmers from exploiting the innovations. The government can also buy these rights on behalf of the smallholder farmers for them to be able to access the new technologies for higher agricultural productivity.

The following table shows simple methodology on how smallholder farmers can build access to complementary assets through various levels of organisational learning over time.

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<sup>27</sup> Scooco, D,(2006).The Teece model. Retrieved from (december 19 2015)

<http://innovationzen.com/blog/2006/08/24/innovation-management-theory-part-5/>

<sup>28</sup> Rodgers, E.M, (2003),Diffusion of Innovations,5th ed, New York: Free press

<sup>29</sup> Kim,2000

<sup>30</sup> UNCTAD,2007. The least developed countries report. Knowledge, techological learning and innovation for development. Geneva.



**Table 1: Building Technological capabilities**

Learning phase	1 <sup>st</sup> level	2 <sup>nd</sup> level	3 <sup>rd</sup> level	4 <sup>th</sup> level
Preparation	Acquiring experienced personnel, literature review, and observation tour.	Literature review, observation tour, foreign personnel	Literature review, observation tour.	Acquiring experienced personnel, literature review
Acquisition	Packaged technology transfer, foreign personnel	Unpacked technology transfer	Unpacked technology transfer	Acquisition by research, overseas R&D foreign personnel,
Assimilation	Learning by doing	Learning by doing	Learning by doing	Learning by doing
Improvement	Learning by doing	Learning by doing	Learning by doing	Learning by doing

Source; Linsu Kim( 2007) cited in Aderemi, H.O, Oyebisi, T. O. & Adeniyi, A. A(2009), p25

Technology capability building is conscious process and requires proper investment into research and Development to realise intended results.

### **3. Innovation capabilities**

The ability of firms to transfer external knowledge, determines how much they can benefit from innovations<sup>31</sup>. To retain their relative competitiveness, these firms must identify cheaper networks for accessing the knowledge. In 2003 Rogers pointed out that firms' inability to find the right knowledge explains why they are often late adopters of innovations<sup>32</sup>.

<sup>31</sup> Paul L. Robertson and David Jacobson,(2011), Knowledge transfer and technology diffusion: An introduction, USA, p8

<sup>32</sup> Rodgers, E. M, (2003), Diffusion of Innovations, 5th ed, New York: Free press.



Proper networks and knowledge clusters as suggested by Beccatini et al.2009 are quite important for smallholder farmers in accessing the right knowledge<sup>33</sup>. This helps the farmers to exchange information freely at relatively reduced costs.

The Innovation capabilities in agriculture encompass development of hybrid seeds, weeding and irrigation technologies that will increase production while reducing time spend on the farm.

For example plant breeders use agricultural biotechnology to produce crops with high yield through gene variations<sup>34</sup>. Biotechnology is commonly used in agriculture to improve crops resistance to pests, have high tolerance to droughts and increase crop yields with less or limited inputs. Biotechnology helps to produce seeds, which requires less fertilizer and other chemical applications but with guaranteed high yields. For example the New Rice for Africa was developed by West Africa Rice Development Association (WARDA) to improve the total yield of African rice varieties. The rice has got a higher yield of 50 per cent without fertilizer and by more than 200 per cent with fertilizer. It also matures very fast and its equally resistant drought. The dry land farmers can improve their incomes by plating this type of rice. This variety of rice has boosted rice production in Benin where agriculture employs 75 per cent of labour and of which 80 per cent of rice farmers are women<sup>35</sup>.

Tissue culture techniques have also been majorly used to increase agricultural output among various types of plants e.g. yams, potatoes, cassava, oranges and tomatoes<sup>36</sup>. The use of micro propagation techniques to potatoes can increase the cropping intensity and improve the food supply to rural families. Micro propagation has actually made potatoes the second most highly produced crop after rice in Vietnam<sup>37</sup>.

In Mozambique scientists have developed a soya variety that has higher yields and are resistant to diseases. Smallholder farmers were harvesting on average 700kg per hectare using the ordinary soya variety but with the new variety the average harvest was 1300kgs per hectare. Their incomes increased by more than 56% during the same period.<sup>38</sup>

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<sup>33</sup> Beccatini, G., M. Bellandi and L. De Propriis (eds)(2009), A handbook for Industrial districts, Cheltenham: Edward Elgar

<sup>34</sup> The DuPont Advisory Committee on Agriculture Innovation and Productivity, 2010.

<sup>35</sup> UNCTAD, p93

<sup>36</sup> Renfro, M.H. (no date). Cloning plants by tissue culture, [csm.jmu.edu/biology/renfromh/pop/pctc/cloning.htm](http://csm.jmu.edu/biology/renfromh/pop/pctc/cloning.htm)

<sup>37</sup> The Economist, 13 October 1990.

<sup>38</sup> USAID Mozambique,2014. Agricultural Technologies: wheels for change in Mozambique . watch <https://www.youtube.com/watch?v=ZiAjNIOHZ9k&feature=youtu.be>

### **Building innovation capabilities**

Another important element in building up innovation capabilities is learning networks. These are learning nodes where innovations begin and diffuse over time. Research and education institutions are very important when it comes to building and sustaining innovations. The research institutions provide prototyping platform where researchers tests new innovations at the incubation centres or laboratories and delivers these innovations to farmers.

Education institutions on the other hand helps build the knowledge that can be subsequently be used to come up with new innovations. They also build capacity to handle the existing innovations. Joint R&D activities by research and education institutions can breed fertile grounds where innovations can sprout. Provision of conducive support services through financial and legal frameworks can also help build innovation capabilities for farmers.

Jensen 2010 underscores the critical role of learning institutions in building innovation capabilities. She argues that technology capability includes the embedded information which must be communicated to farmers effectively<sup>39</sup>.

In summary, developing technology capabilities is an investment process which has to be cognizant and persistent.

Lall in 1996 asserted that the process must be conscious and purposeful<sup>40</sup>. For the capabilities to be established the farmers must learn by doing through technological effort.

Formal education, operational structures and scientific knowledge are inevitable for successful development of technological capabilities. Experience is therefore important in developing these capabilities, which is only effective if farmers learn by doing over a period of time<sup>41</sup>. This experience is not involuntary but actively acquired slowly over time. Dahl-man et al in 1987 also confirmed that the technology development process must be conscious and farmers/actors should

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<sup>39</sup> Jensen, R., 2010. Information, efficiency, and welfare in agricultural markets. *Agricultural Economics* 41(s1): 203–216. doi:10.1111/j.1574-0862.2010.00501.x

<sup>40</sup> Lall, Sanjaya. 1996. *Learning from the Asian Tigers: studies in technology and industrial policy*. Basingstoke: Macmillan Press.

<sup>41</sup> Lindsay W, 2010. *Developing Technological Capabilities in Agro-Industry: Ghana's experience with fresh pineapple exports in comparative perspective*, Ghana.

be willing to try new things, incrementally develop existing old technologies and keep track of new developments<sup>42</sup>.

Building innovation capability can be influenced by the following factors;

- Government's agricultural technology policies.
- Funds available for developing technology capabilities
- Technological information and other support services
- Right amount of skills acquired through training
- Organic farming incentive structures

### **Framework conditions**

Adoption of technologies from developed world to smallholder farmers in the emerging markets has often met insurmountable challenges. This is quite often during implementation phases of the technologies. Appropriate framework conditions are therefore necessary to ensure that technologies are successfully adopted, adapted and diffused to farmers. The framework conditions are discussed below.

### **Legal framework**

Legal frameworks are very important in providing guidelines on the usage and adoption of agricultural technologies. The Agricultural Act in Kenya for example contains rules and regulations on matters relating to land ownership; promotion of efficient land use and proper land husbandry<sup>43</sup>. Agricultural Appeals Tribunal provides legal redress to farmers in cases where their rights have been violated. Strong intellectual property rights not only protect farmers' innovative ideas but also acts as an incentive to them to innovate more agricultural technologies.

### **Technical support**

This is a very important part in ensuring technologies are easily adopted and diffused. Technologies always carry tacit knowledge, which is not always transferred when technology assets are sold. Building the absorptive capabilities for smallholder farmers therefore depends on

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<sup>42</sup> Dahlman, Carl, Bruce Ross-Larson, and Larry Westphal. 1987. Managing Technological Development: lessons from the newly industrializing countries. *World Development*15(6): 759-75.

<sup>43</sup> The constitution of Kenya, 2010.

how much technical support they get to enable them fully understand and manage the new technologies.

Most technology developers always include user guides in most of their technology gadgets but they are not customized to meet specific needs of individual farmers. In cases where farmers are illiterate, provision technical support through customised training provides an effective way of ensuring technologies diffuse to local smallholder farmers. Technical support services in Kenya are carried out mostly by extension officers<sup>44</sup>.

### **Education frameworks**

Education is a major factor when it comes to knowledge transfer. Well educated farmers easily understand the need to have new technologies and where to get them. They also make informed decision when choosing seeds and the agricultural practises in general. Training programs for farmers by agricultural actors e.g. Universities and Research institutions greatly impacts on the rate at which technology diffuses. Farmer to farmer knowledge diffusion is enhanced if the farmers involved are literate. Well functioning education frameworks is a great pillar in sustaining absorptive capabilities of farmers.

### **Financial frameworks**

Financial institutions play a vital role in ensuring technology is diffused to farmers. Partnerships between financial institutions and research centres ensure that funds are available for R&D activities. Similarly, financial institutions provide credit facilities to farmers to enable them buy better farm inputs for improved agricultural productivity. In Kenya for example, Equity Bank provides loans at affordable interest rates to smallholder farmers to enable them expand their production capacities<sup>45</sup>. A proper financial incentive system in agriculture ensures more funds are channelled towards agricultural research to build technology capabilities of farmers.

### **Actors in Agricultural technology capability process**

Adopting new technologies into farming systems isn't easy. It more than often involves creative destruction as suggested by Schumpeter model<sup>46</sup>. Farmers have to abandon old ways of doing agriculture in favour of new ones if they have to remain competitive. Adopting these technologies especially smallholder farmers isn't a walk in the park, it's an investment process

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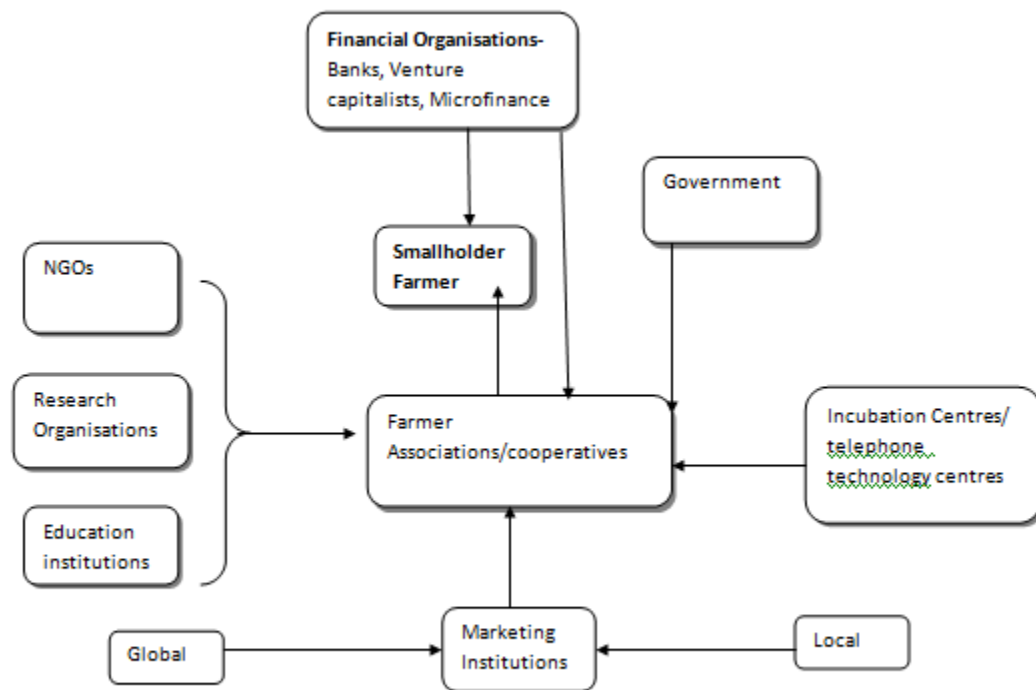
<sup>44</sup> World Bank,(1999),Agricultural Extension. The Kenya Experience, Kenya.

<sup>45</sup> Equity Bank,(2013),Partnering with farmers for food security, Kenya.

<sup>46</sup> Aghion et al..2014. The Schumpeterian Model. See

[http://www.econ.brown.edu/fac/Peter\\_Howitt/2070-2015/Ch5-Schumpeter\\_140521.pdf](http://www.econ.brown.edu/fac/Peter_Howitt/2070-2015/Ch5-Schumpeter_140521.pdf)

involving substantial amounts of money. This is partly why smallholder farmers resist new technologies despite its huge potential benefits. They therefore need reliable networks of several actors who may help them assess their technological needs and adapt them into farming activities. The following flow chat describes the various actors involved in technology capability building for farmers and their specific roles in the innovation process.



**Figure 2: Actors in Technology capability Building process.**

**Source; Author, (201)**

Their roles are described as below.

**Research and incubation centres.**

Research and incubation centres are perfect places where innovations can be developed and diffused. Research and incubation centres have been described together due to their intertwining roles. The Kenya Agricultural Research Institute provides a platform where agricultural technologies and innovations are developed, shared and diffused to improve productivity of

smallholder farmers in Kenya<sup>47</sup>. They have been able to develop high breed maize seeds and other seeds that adapts well to climatic conditions in Kenya.

The Kenyatta University Chandaria business innovation and incubation centre also provides mentoring and start up grants up to \$200,000 to innovative ideas in many fields including biotechnology<sup>48</sup>. This is platform where agricultural innovations can be developed and diffused to smallholder farmers in Kenya.

### **Education institutions**

As Merleba and Richard put it, education institutions are very crucial for innovation process in any given country. They affirm that many developing nations have been successful in catching up by establishing robust basic education systems to provide training and skills required in the whole innovation processes<sup>49</sup>. Universities especially agricultural based, provide educational training to students on modern agricultural practices. They also offer a supportive environment for new innovations. These basic innovations can be tailor made to meet the needs of smallholder farmers. Nelson 2006 adds that universities play a big role in basic and applied research, biotechnology and software that are very crucial in any innovation process. Universities remain good platforms where technology capabilities can be developed and subsequently diffused through adequate training.

### **The government**

The government remains a major stakeholder in the innovation and technology capability building process. They do so through protection, direct or indirect subsidy as the case of China, Taiwan, and Japan<sup>50</sup>. The government provides enabling environment for the innovation process. This may include provision of relevant basic infrastructure, policy and organisational frameworks and other incentive schemes to promote innovation culture.

For example the US government in the early 1980's put an elaborate biotechnology strategy to protect and develop the agricultural industry.

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<sup>47</sup> Kenya Agricultural Research center,2015 December 13 .Retrieved from <http://www.rdcoe.or.ke/node/17015>

<sup>48</sup> The Kenyatta university Chandaria business innovation and incubation center, 2015 December 13. Retrieved from <http://www.ku.ac.ke/chandaria-biic/>

<sup>49</sup> Franco Marleba and Richard Nelson,2010. Catching up in different sectoral system. Evidence form six industries.

<sup>50</sup> Marleba,2010

Germany and French governments are now supporting highly centralized biotechnology programs while UK and Australia sought to stimulate private sector investments through a number of fiscal measures<sup>51</sup>. Government can also support innovation process by providing funding for R&D projects.

### **Financial institutions**

Technology innovations are considerably expensive. They need to be funded in one way or another. Financial institutions support innovation process by providing funds needed for prototyping and testing of innovations before farmers finally use them. Building technology capabilities sometimes requires huge capital investments which smallholder farmers cannot afford hence the support from banks and other micro finance institutions.

### **Diffusion of technologies and technology capabilities**

#### **a. Technology diffusion processes**

The rural farmers' ability to catch up is purely depended on how fast they will accumulate technological competencies and adapt them to their farming systems. Adopting new technologies from developed countries in some cases fails to work in developing nations due to infrastructural challenges and inadequate skills and competencies of the local staff. Because of this technological learning becomes the most appropriate way of diffusing technologies to rural farmers.

This is a process where local farmers accumulate their own technologies/knowledge that suits their local environment over time to gain competitive edge in agricultural value chain (see also Raghavendra et al). These technological capabilities include capabilities to access complementary assets, absorptive capabilities and innovation capabilities<sup>52</sup>.

Agricultural innovations have the potential to increase the productivity of smallholder farmers. They result to less production cost which can be measured by less time spend working in the fields and less money used to buy additional farm inputs like pesticides. Apparently these innovations tend to be heavily concentrated in developed countries which have the ability to invest heavily in R&D. Smallholder farmers in technology deficient nations often depend on

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<sup>51</sup> Juma and Calo, 2002. The Case of Agricultural Biotechnology in the United States, USA.

<sup>52</sup> Franco Marleba and Richard Nelson, 201. Catching up in different sectoral systems: Evidence from six industries, p6



innovation spillovers from technology frontier nations through imitations and “follow on” innovations<sup>53</sup>.

Technology diffusion among smallholder farmers is always challenging. Smallholder farmers are characterised by exclusion effect. This refers to cases where farmers persistently resist taking up new technologies in their farming practices.

They stick on their conventional farming ways despite the perceived benefits in the new farming technologies. The fear of risks and uncertainty of possible financial losses, are the major barriers for diffusion of innovations among smallholder farmers. Inadequate access to price and demand information creates uncertainties about expected profits of new technology thus discouraging smallholder farmers to adopt it<sup>54</sup>.

A farmer’s decision to take up new innovation depends on a number of reasons<sup>55</sup>.

They include;

- Perceived advantage of the new innovation
- Degree of compatibility with the existing innovations
- Easiness of use
- Degree to which the innovation can be tried before use
- Observable results

Technology innovations can diffuse to smallholder farmers in different ways .They are discussed in the following broad categories

### **i. Absorptive capabilities**

Firstly, peer-to-peer conversations with farmers and farmer networks can greatly increase the rate at which innovations are diffused and adopted among smallholder farmers. Use of social networks and mobile phones to disseminate extension services to farmers can act as a diffusion

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<sup>53</sup> Evenson, R. and L. Westphal (1995), “Technological Change and Technology Strategy”, in J. Behrman and T. Srinivasan (eds.), Handbook of Development Economics, Vol. 3A,pp. 2209-2229 (Amsterdam: North Holland Publishing Company).

<sup>54</sup> Abadi Ghadim, A.K., Pannell, D.J., 1999. A conceptual framework of adoption of an agricultural innovation. *Agricultural Economics* 21(2): 145–154. doi:10.1016/S0169-5150(99)00023-7

<sup>55</sup> Everett M. Rogers, *Diffusion of Innovations*, Fifth Edition 2003, Free Press, New York, p221

channel where technology reaches the farmers. They are more effective than media persuasions<sup>56</sup>. Farmers are able to learn from their fellow farmers through observations thus overcoming their fear of the unknown about the new technologies.

In addition, technology can be diffused through imitation. This is an informal way, where farmers and researchers temporarily move to seek for the information in techno savvy companies and farmers. It also involves exchange of staff or students from technology deficient farms to frontier farms to acquire specific knowledge for local use<sup>57</sup>. Import and export transactions also provide avenues where knowledge and technology can diffuse.

Grossman and Helpman in 1991, argued that buyers or clients feedbacks and complaints or suggestions on how to process agricultural goods before dispatching them for sale, provides farmers a chance to access the knowledge of their clients thus boosting their technology capabilities

However, it should be noted that this is only knowledge based approach where only absorptive capabilities of the farmers are build. Local framework conditions e.g. appropriate infrastructure has to be in place for the knowledge to fully diffuse.

## **ii. Access to complementary assets**

Acquiring the knowledge alone may not be enough for successful diffusion of innovations. Complementary assets and other relevant infrastructure must be available for the innovation to be fully integrated locally. Intellectual property rights are therefore important in ensuring innovations are diffused from the source to where they actually needed. Several studies confirm that strong intellectual property rights stimulate innovations in emerging markets<sup>58</sup>.

Intellectual property rights have got the potential to encourage technology transfer through trade, Foreign Direct Investments, licensing and through venture capitalists<sup>59</sup>. This ensures farmers in emerging markets gain direct access and uses technology assets developed elsewhere.

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<sup>56</sup> Everett M. Rogers, *Diffusion of Innovations*, Fifth Edition 2003, Free Press, New York, p221

<sup>57</sup> UNIDO,(2006), *The Role of Intellectual Property Rights in Technology Transfer and Economic Growth: Theory and Evidence*, Vienna.

<sup>58</sup> Chen, Y. and T. Puttitanun (2005), "Intellectual Property Rights and Innovation in Emerging markets", *Journal of Development Economics* , 78, pp. 474-493.

<sup>59</sup> UNIDO,2006.p23

This might be through investments into subsidiary companies, investment partnerships, non market transactions and knowledge spillovers. Traded in goods and intermediate goods may stimulate innovation in the local firms through reverse engineering.

Foreign investors may also deploy technology assets and staff to local firms thus diffusing the new technologies for commercial exploitations. Licensing by giving exclusive rights to exploit technology is also another way in which technologies are diffused thus making access to complementary assets much easier and cheaper for improved agricultural productivity.

Though it has been pointed out that strong intellectual rights stimulate innovation in some case it prevents innovation diffusion to technology deficient farmers. Patents prevent smallholder farmers from accessing the patent knowledge and they are often expensive to buy. Since diffusion of technology depends on country specific circumstances, there is a need to strike a balance when a strong intellectual rights policy and when to loosen it to promote technology diffusion.

South -South Cooperation (SSC) policies in the field of agriculture are also a good example of how technology can be diffused to smallholder farmers in emerging markets. These policies which were defined in the Buenos Aires Plan of Action of 1978 mandated emerging markets to share knowledge, experience, technical expertise, suitable technologies and financial assistances while the developed countries serving to smoothening the progress of these South- South linkages through triangular partnerships<sup>60</sup>. This diffusion method is based on the benchmarking model illustrated in Table 4. Building technology capabilities ((Linsu Kim( 2007) cited in Aderemi, H.O, Oyebisi, T. O. & Adeniyi, A. A(2009), p25))

### **iii. Innovation capabilities**

These capabilities refer to the ability of farmers to adopt new technologies, adapt them and implement them for economic gains. This can be measured by how much a firm invests in R&D activities. Access to foreign technology alone cannot guarantee technology diffusion but also the local abilities to absorb and implement such technology. This is achieved if a firm continually invests into local R&D activities to provide basic infrastructure necessary for integrating the new

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<sup>60</sup> UNOSSC,1978.Global South South Development Policy. Retrieved from (December 10. 2015)  
<http://ssc.undp.org/content/ssc/services/policy.html>

knowledge. Various studies indicate that firms with high absorptive capabilities are likely to benefit from foreign R&D spillovers hence becoming even more innovative<sup>61</sup>.

Chinese ICT sector grew steadily and managed to catch up with those in technology frontier nations through prioritizing investment in R&D<sup>62</sup>. The green revolution is a perfect example of how technology has been established and diffused from India to other parts of the world. It marked the beginning of improved agricultural productivity when it was initiated after the Second World War<sup>63</sup>. Green revolution technology has been successfully diffused and adopted in many developing nations. In the pioneer countries like India the grain production doubled between the periods of 1950-1992<sup>64</sup>.

Other countries like Brazil also experienced increased output and productivity in basic cereals like wheat and rice<sup>65</sup>. Green revolution at its inception involved using high quality seeds of rice and wheat. During this time modern agricultural equipments and practises e.g. chemicals fertilizers, pesticides, electrical and diesel powered pumps were commonly used<sup>66</sup>. They replaced the conventional subsistence methods which were less efficient and often relied on the availability of rains.

To develop technology capabilities effectively other stakeholders have to be actively involved. These stakeholders are the actors or agents who ensure innovations are adopted and incrementally developed to suit them to local need for farmers. These actors can operate independently or in partnership to ensure innovations are successfully diffused among farmers.

### **b. Gender gaps and technology in agriculture**

Technology use in agricultural activities has been credited for various benefits. As pointed out earlier the adoption and use of technology is positively correlated to the level of education of the user. Since women have less education opportunities and training services, their ability to adopt and exploit new technologies are limited. Inadequate access to credit facilities also limits them from accessing new farming technologies. Studies done by Peterman, Quisumbing and Behrman

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<sup>61</sup> Crespo-Cuaresma, J., N. Foster and J. Scharler (2004), "On the Determinants of Absorptive Capacity: Evidence from OECD Countries", Current Issues in Economic Growth, Proceedings of OeNB Workshops (Vienna: Austrian National Bank), pp. 58-81.

<sup>62</sup> Paul L. Robertson and David Jacobson,(2011), Knowledge transfer and technology diffusion: An introduction, USA, p8

<sup>63</sup> P. Fitzgerald-Moore and B.J. Para, (\*no year). The Green Revolution.

<sup>64</sup> P. Fitzgerald-Moore and B.J. Para, (\*no year). The Green Revolution.

<sup>65</sup> Govindan,p72

<sup>66</sup> Govindan,p72

in 2010 highlights the significant gender variations in exploiting new agricultural technologies<sup>67</sup>. In other related studies in Burkina Faso for example women use less fertiliser per hectare than men<sup>68</sup>.

In Ghana, due to less access to land and extension services, only 39 percent of women used new improved varieties of seeds as compared to 59 percent of male farmers<sup>69</sup>. Lack of funds was also reported to be the major factor hindering women farmers in Kenya, Malawi and Benin from using fertilisers in farming<sup>70</sup>.

As per FAO's assessments in 2011, food yields may increase by 3-4 per cent and undernourishment reduced by 12-17 percent if women accessed proper technology<sup>71</sup>. Its therefore very important to consider gender issues when planning for technology diffusion programs for increased competitiveness of smallholder famers especially for women.

### **c. Enhancing Technology diffusion among smallholder women farmers**

We have already discussed how technology capabilities are developed and consequently diffused from frontier markets to reach rural smallholder farmers. We also saw the gender gaps in organic farming where women farmers have limited access to education, extension services, financial services and inadequate access to technology. But as indicated earlier, women provide the majority of labour force in developing nations Kenya notwithstanding thus being a special interest group to consider when enhancing agricultural productivity of smallholder farmers. Empowering smallholder women farmers calls for increasing their access to technology and other modern farming inputs e.g. seeds and fertilisers.

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<sup>67</sup> Quisumbing, A .R. & Pandolfelli, L. 2010. Promising approaches to address the needs of poor female farmers: resources, constraints, and interventions. *World Development*, 38 (4): 581–592.

<sup>68</sup> Udry, C., Hoddinott, J., Alderman, H . & Haddad, L.1995. Gender differentials in farm productivity: implications for household efficiency and agricultural policy. *Food Policy*, 20(5): 407–423.

<sup>69</sup> Doss, C. & Morris, M . 2001. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics*, 25 (1), 27–39.

<sup>70</sup> Minot, N ., Kherallah, M . & Berry, P. 2000. *Fertilizer market reform and the determinants of fertilizer use in Benin and Malawi*. Markets and Structural Studies Discussion Paper No. 40. Washington, DC, IFPRI.

<sup>71</sup> HLTF. 2011. Food and Nutrition Security: Comprehensive Framework for Action, Summary of the Updated Comprehensive Framework for Action. New York, NY: United Nations.

According a World Bank report, 98 per cent of economically active women in Tanzania are involved in Agriculture and the majority reside rural areas<sup>72</sup>. 56 percent to Rwandan women have no access to formal financial services<sup>73</sup>.

These women practice labour intensive agricultural whose output is generally low and in addition they have to do other household chores. Due to their poor status and high illiteracy levels, their ability to acquire and use technologies or be potential leaders in technology innovations is minimally low. In fact, in the highly male dominated commercialized agriculture, introduction of technology reduces workloads for men while increasing that of women farmers<sup>74</sup>.

The table below shows the gender difference in technology adoption in Kenya.

Type of household head	%Households using			Total percentage
	modern implements in land preparation (plough/tractor)	mainly indigenous implements in land preparation (traditional hoes)	both modern and traditional implements	
Male headed	60 (24)	34 (14)	6 (2)	100
Female headed	20 (12)	79 (47)	1 (1)	100

**Figure 3: Gender and Technology use in agriculture in Machakos Kenya**

**Source: ATPS working paper, No 38.**

Based on the above table, it's clear that women farmers have less access to modern technology in Kenya as compared to Male farmers. Their limited access to technology runs right from development to diffusion stages of technology capability discussed above. Inadequate access to education and training makes women unable to use and handle the available technologies. Purchase of such technologies is equally an uphill task for them due to their poor financial status. Technology diffusion among smallholder women farmers is hampered by both inadequate access to the technology innovations and the inability to exploit the available technologies due to high costs or illiteracy or both.

<sup>72</sup> Worl Bank, 2007. Gender and Economic growth in Tanzania. Creating Opportunities for Women, Washinton DC.

<sup>73</sup> Rwanda 2010 Implementation plan. Retrieved from on 02 Jan 2016.

<http://partneringforinnovation.blogspot.de/2014/03/women-and-agricultural-technology-whats.html>

<sup>74</sup> Palmer, I. (1978). Women and the Green Revolution. A Paper Presented to the Conference on the Continuing Subordination of Women and Development Process. Sussex Institute of Development Studies.

Improving the use of mobile phones and mobile applications can be a better way of enhancing technology diffusion among smallholder women farmers. Agricultural extension and technical support services can be disseminated through the use of mobile phones. According to World Bank report 2010, 80 to 98 percent of women farmers Ghana, India, and Ethiopia could not access extension services due to physical barriers or lack of time<sup>75</sup>. In Bangladesh poultry farmers use mobile phones to sell their chicken and chicken products direct to buyers thus substantially increasing their incomes and also gaining access to market information<sup>76</sup>.

Proper education training to women and farmers is also another avenue to ensure women have the capabilities to adopt and use new technologies. Adult education through extension services in rural areas targeting women farmers should be given due priority to build the knowledge base necessary for technology transfer processes. Mass media campaigns to fight general stereotypes against women farmers could help attract women to embrace new technologies available to them in rural areas. Cocolink program established by World Cocoa foundation in Ghana for example uses voice messaging to reach out to illiterate women farmers<sup>77</sup>. In Uganda the Grameen Foundation provides child care services to women when undergoing trainings on how to use agricultural technologies such as mobile phone applications and also when they are providing extension services to other farmer organisations<sup>78</sup>.

## **CONCLUSION**

Emerging economies appear to be laggards as far as innovation technology is concerned thus making it hard to develop competitive economies. Majority of these economies are agro based with little or no value addition to the agricultural produce. Inadequate technology penetration in key sectors like agriculture makes these countries perform relatively poorly globally. To achieve relative competitiveness in agricultural sector, there must be deliberate efforts to develop various forms of technology capabilities. These capabilities were absorptive capabilities, innovative capabilities, and access to complimentary assets. The author further discussed the relevant framework conditions like legal frameworks, education and financial support systems that would ultimately sustain the technology transfer process. For the continent to tap her agricultural

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<sup>75</sup> World Bank,(2010).Access to Extension services for women farmers in developing nations.

<sup>76</sup> UN Women,(2011), Rural Women's Access to Science and Technology in the Context of Natural Resource Management, Accra Ghana.

<sup>77</sup> Cocoa Foundation,(2011), CocoaLink – Connecting Cocoa Communities. Retrieved from (02 Jan 2016) <http://worldcocoafoundation.org/cocolink/>

<sup>78</sup> Grameen Foundation,2014. See also <http://partneringforinnovation.blogspot.de/2014/03/women-and-agricultural-technology-whats.html>



potential, there must be adequate technology transfer mechanisms put in place to sustain agricultural productivity that would eventually boost these agro economies.

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