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Review Article

Human Capital and the Growth of Biotechnology in Developing Countries

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Abstract: The life sciences offer opportunities for revolutionizing human welfare activities. Enriched by inputs from genomic research, biotechnology is a major force for development in all countries. Entwined with culture and socio-ethical values, biotechnology contributes to solving problems like food and water insecurity that impede national development and threaten peace in the developing world. The lack of facilities and professional skills in biotechnology limits R & D initiatives in the developing and the least developed countries (LDCs); and, restricts their full participation in take-off activities in national and self-reliant regional ventures in sustainable development. The practice of biotechnology in many developing countries is nevertheless impressive. The establishment of biotechnology in terms of human capital and growth in several developing countries is indicative of biotechnology being accorded high policy status in national development; of its significance in the eradication of poverty; and of its use in the empowerment of humans in applying the technology for human and social welfare. This review provides information about how human capital has encouraged the growth of biotechnology developing countries.

Keywords: Biotechnology, Empowerment, Countries, Establishment.

INTRODUCTION

For developing countries, the promise of biotechnology is particularly strong. Problems associated with population pressures, food insufficiency, and nutritional deficiencies, environmental degradation, and the need to create employment could well be partially solved by new technological innovations presented by advances in biotechnology. However, to face these challenges, governments in developing countries must develop appropriate plans and policies, and invest in capacity building (Becker 1993).

The Global Innovation Index (GII), 2014 surveyed 143 economies around the world, using 81 indicators to gauge both their innovation capabilities and measurable results. Mauritius, which tops the African countries in the ranking, came at the 40th position, followed by South Africa at 53rd and Tunisia at the 78th position. Nigeria was placed at the 110th position. The foregoing GII ranking has shown that in a global and dynamic world, the economies that can remain flexible, adaptive, and innovative will reap the benefits of world trade. This is because the global competitiveness of any economy depends on its science, technology and innovation (STI) capabilities (Lynham and Cunningham 2006).

In all ramifications of economic development, technology-dependent economies surpass economies dependent on their natural resources. However, there remain challenges to the diffusion of technology in Nigeria. First, the law does not encourage technological innovation. Its capability to protect prospective innovators remains in doubt. Furthermore, Nigeria lacks human capital to manage effectively its sectors. Moreover, research facilities in the country are either inadequate or outdated. There are no effective policies to serve as incentives to arouse local innovators and to attract foreign investors. Nigerian technological environment is discouraging. Modern infrastructures are also required to encourage foreign direct investment (FDI) (Nafukho *et al*, 2004).

Human capital (HC) is an aggregation of knowledge, skills, abilities, and competencies, acquired by human beings over the course of their lives, developed through participation in various forms of formal and informal education and training, and utilized in productive activity for the benefit of individuals,

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organizations, and society (Becker 1993). Human resource development (HRD) research suggests that investment in people results in improved performance on the individual level, improved productivity on the organizational level, and economic development and other benefits on the societal level (Lynham and Cunningham 2006) (Nafukho *et al*, 2004). Several HRD scholars documented the processes and outcomes of investment in human capital in individual countries (Osman and Chan 2009). However, comparative research on HC development is still limited and comparisons involving multiple countries are especially scarce.

Biotechnology is the "application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or nonliving materials for the production of knowledge, goods, and services" (Van Beuzekom and Anthony 2006). Relevant technologies include genetic, protein, cell, and tissue engineering, with applications in human and veterinary health, agriculture, industrial processing, and other fields.

Biotechnology in the world

Policymakers all over the world have bestowed almost iconic status on biotechnology as a somehow "revolutionary" technology. But a careful examination of knowledge generation and application from the sciences to the clinic shows that the process of translating advances in biosciences to commercially viable technologies is a gradual and arduous process that takes (a long) time and plenty resources. Complementary innovations and very different organizational changes in drug discovery and development and in clinical practice have accompanied the expansion of biotechnologies into growing forms of applications. So biotechnology has developed together with traditional pharmaceutical activities, rather than revolutionizing the life sciences (Hopkins *et al* 2007).

Biotechnology for the Developing Countries

There is no doubt that biotechnological sciences offer a large number of flexible techniques which can be applied to many areas, although it is also true that these techniques have not emerged in a vacuum, in addition to their not being inert as regards their socio-economic and political consequences. During the last few years, an optimistic literature has appeared according to which biotechnology is seen as the panacea that will solve the problems of the developing countries. There are also authors who attest precisely to the contrary. At the outset, it can be said that the best position from which to make decisions in this field in the developing countries will be one that excludes extreme positions (Hopkins *et al* 2007).

To this end, the possible positive or negative effects of biotechnology upon the following aspects must be borne in mind (Sasson and Costarini 1991).

- Increase in farming productivity and in food production, through the direct use of plant biotechnology, complementing conventional technologies.
- Nutrition, through improvement in farming and agro-industrial production, and techniques of fermentation in food processing.
- A better integration of food production and consumption of bioenergy at the household and small settlement levels.
- Improvement in livestock production and in the health of domestic animals.
- Correctness in diagnosis and prevention of diseases, as well as upon public health.
- Commercial exchange patterns between developing and industrialized countries, as a result of differences in dynamics in the introduction of productivity improvements both in farming and agro-industrial activities; also, of the marketing of new biological products which have a tendency to displace raw materials and products from the developing countries, depriving them of an important source of revenue.
- Income and employment.
- The possible expansion of cash crops at the expense of food producing crops. Strengthening of large farming operations, with the subsequent displacement of small farmers.
- Possible reduction in genetic diversity as a result of the broad distribution of new crops.
- The increasing privatization of the results of research, to which the developing countries do not have easy access, being forced to paying fees for the use of seeds and plant varieties developed by the industrialized countries.

We can see that the preceding factors can have far reaching consequences. In addition, we expect that the adoption of new biotechnologies by the developing economies will be concentrated in the sectors of greatest economic development potential, will increase internal social differences and concentration of ownership of farmland, and bring greater poverty to small producers and hired manpower. This will also bring about an acceleration of migrations from rural areas, while increasing the cost of medicines and other health products, etc. (Juma and Ismail, 2007).

A review of biotechnology in Africa for the AU and NEPAD concluded not only is biotechnology key to Africa's development but also what it would take to promote existing, disparate initiatives to a higher level. More precisely, this would incorporate regional innovation communities – as physical and virtual clusters of people and organizations – where individuals and institutions share skills and expertise in the pursuit of common goals. Investment in human resources, especially in experts in molecular biology, biochemistry, and bioinformatics, would be needed to

achieve larger capture of the biotechnological value chain on the continent (Juma and Serageldin 2007). Within Africa, South Africa has particular strengths in food and medical biotechnology. Sizeable proportions of yellow maize and cotton planted are genetically modified. The country has also developed an insect-resistant potato. In the animal sciences, the University of Pretoria and Onderstepoort Veterinary Institute, in conjunction with international partners, developed and launched a molecular diagnostic testing kit for tick-borne diseases found in livestock. South Africa also leads the exploitation of biotechnology in manufacturing, notably in the substitution of synthetic chemicals with biological alternatives (Sasson and Costarini 1991).

The AU/NEPAD report therefore recommended that Southern Africa be principally responsible for health biotechnology within the regional distribution of competences and concentrations across the African continent. Suggested priorities for R&D and innovation include:

- The development and testing of AIDS vaccines;
- The development of transgenic plant-based platforms for the cost-effective expression of specific molecules;
- The exploration of affordable remedies for people living with HIV/AIDS;
- The development of anti-malarial drugs from indigenous plants;
- The combating of drug resistance in the malaria parasite;
- The testing of efficacy of plants used in the traditional treatment of tuberculosis (Juma and Serageldin 2007).

Also in many developing countries patent law is either outdated or non-existent. There is a need for training biotech entrepreneurs in the value and usefulness of patent and intellectual property legislation. Though several developing countries are signatories to international conventions, enactment of subsequent national legislation is slow or still in the pipeline. Lessons learnt indicate there is a clear need for capacity-building and of good practices in the scientific, legal and ethical aspects concerning intellectual property (Juma and Serageldin 2007). Developing countries and LDCs are already devising and using strategic biotechnologies to solve problems of local, regional and global significance. Their participation in several regional and international pedigree programmes contributes to an on-stream worldwide resource that reflects to some extent, the human face of globalization. Flexibility, scientific co-operation, and co-shared funding help developing countries respond to the common challenges that involve biotechnological solutions for the benefit of all humankind. South-South collaboration and capacity-building in technical development and economic co-operation programmes have proven useful in the transfer of biotechnology (Kornhauser 2001).

Human capital influences on biotechnology in developing countries

- **Sustainable economic growth requires innovation and adequate human capital and employment;** In the 2030 Agenda for Sustainable Development (Slovenia, 2001), which places people, planet, prosperity, peace and partnership at the center of an action plan encapsulated in the Sustainable Development Goals, economic growth, enterprise creation and employment opportunities represent a key building block that is articulated in SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

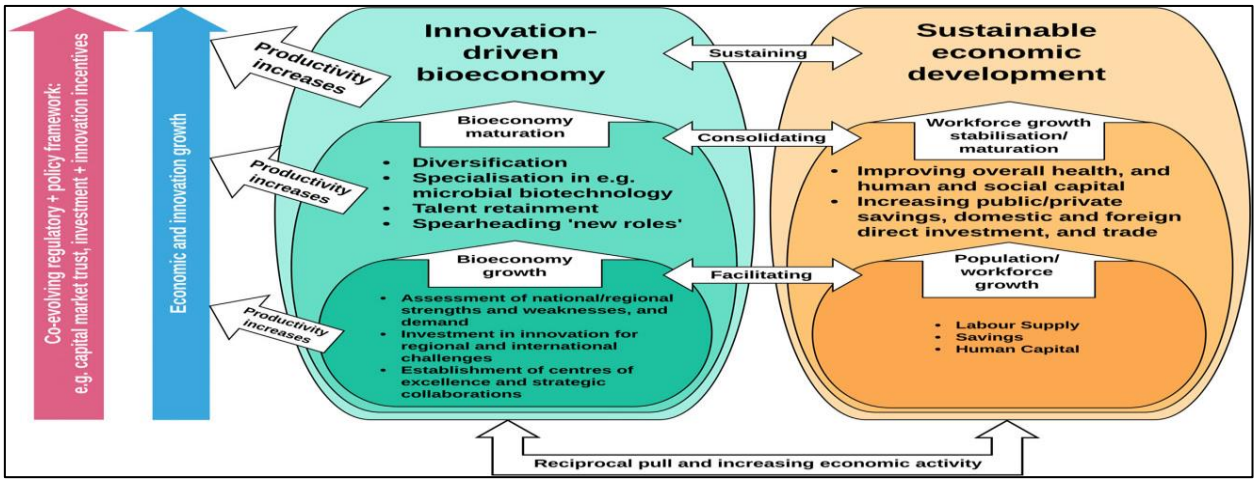

Fig. 1. Growing the bioeconomy and increasing the demographic dividend to enhance economic development – illustration in part based on Bloom *et al.*, 2003; McTaggart *et al.*, 2012.

In most developing countries, the private sector is weak. There are only a few industries capable of acquiring and assimilating new biotechnologies and then producing and commercializing new products in

the global market. Indigenous industries generally prefer to buy technologies from the world market. Industries affiliated with transnational corporations draw most of the research and development needed for their manufacturing activities from their headquarters. This situation creates a climate in which transnational corporations have no urgent need for new technologies to be derived from research and development work supported by the public sector. Unless this condition is altered by developing better relationships between the public and private sectors, the results of biotechnology research produced by the private sector may not be made available to the public sector corporations. There are also a number of structural problems that must be resolved as well. For example, the over-valued currency in a country like Cote d'Ivoire makes it more attractive to import the raw material at a disguised subsidized price than to prepare this raw material locally for further processing and marketing on the local market (Slovenia, 2001),.

- **Training of Human Resources**; Biological resources are the raw materials used by biotechnology processes. Of these, it is the plant genetic resources that are most widely used in biotechnology. Alone, these resources mean little to a country. They require human skills and the appropriate technologies to achieve their potential. Included in the required technology is a delivery system. There is a widespread agreement that modern biotechnology requires the development and application of biochemistry, microbiology, molecular biology, and genetics. As a result, any biotechnology program will have to assign high priority to strengthening human resources training in these areas. An associated difficulty is "brain drain", which is particularly important in biotechnology. For this reason, training should take place, when possible, at centers of excellence in the developing country of origin or another developing country. Expert human resources in general are rather limited in the developing world. Trained personnel often have many duties (such as administration) and are left with no time to do research. However, it is research that enhances technology acquisition, adaptation, and development (Kornhauser 2001).

- **Financing and Evaluation;** Funding for biotechnology should cover the development of infrastructure, basic research, contribution of venture capital (for technological development and investment), scholarship programs, and exchanges with other countries. Funds should be allocated in accordance with established priorities. However, although many countries have made biotechnology one of their top priorities in their research and development agenda, there are large differences in the commitment of resources. Research in biotechnology can cover a wide range of topics and be undertaken at different levels of sophistication. In many developing countries these activities have led to the mastering of new techniques in biotechnology. Quite often, however, this capability is scattered throughout different research units (Kornhauser 2001).

- **Information**; Access to technical information enhances access to new technologies and can strengthen a country's negotiating position with outside agencies. A network of libraries and technical documentation centres that incorporates the latest advances for retrieval, storage, and dissemination of information should be provided. As well, scientists need to attend regional meetings to share ideas (Osman and Chan, 2009).

- **Enterprise Development;** An efficient mechanism for biotechnology dissemination is the creation of so-called knowledge enterprises. In key areas, national or regional companies can be promoted and protected until they become established in the market (Osman and Chan, 2009).

- **Safety;** The application of biotechnology is not free from danger. Training courses should be organized on safety measures and supported with manuals and other training materials (Sasson and Costarini, 1991).

- **Purchasing Policies of the Public Sector;** The public sector is the largest buyer in any country. Therefore, it can promote national technologies by purchasing goods produced by means of new biotechnologies (Kornhauser 2001).

- **Fiscal Incentives;** It is important that the private sector make a contribution to national research and development. For this reason, governments should provide incentives for research and development activities, for the creation of infrastructure and information, and for the training and development of human resources (Juma and Ismail, 2007).

DISCUSSION AND CONCLUSION

Biotechnology is a motor of technological advancement in both the developed and developing countries though at different levels in scope and content. The simple production of cheese and fermented foods to the industrial production of antibiotics and the genetic elaboration of biopharmaceuticals and novel crops illustrate the breadth and depth of biotechnology endeavor and practice worldwide (Slovenia, 2001).

Biotechnology has the potential to modify and improve the economic and social conditions of the population living in the developing world. On long term, it will create a new "revolution" in the agriculture worldwide. Biotechnology may well generate a greater impact in this sector than the so-called "agro-chemical revolution". It will give the possibility to the developing countries to improve their self-reliance on adequate quantity and quality of food and to increase their competitiveness on the international commodity markets (Bloom *et al,* 2003). Biotechnology has also

the potential to resolve difficulties in the health as well as the energy sector of many developing countries or to help in the resolution of difficult problems such as the reduction of the population growth in some of the countries. However, in order to produce all these benefits, it is essential that appropriate policies and instruments be adopted in the developing countries themselves to promote research, development, and transfer of technologies and their marketing to the end users (Bio, 2017).

The development of a critical mass of motivated scientists is a crucial element in all the countries. More resources from the development assistance agencies should be devoted not only to the training of these scientists but also to the building of appropriate physical environments where they can execute their research works. However, where the country economy is too small to generate the necessary critical mass of scientists, every effort should be made to generate multi-country initiatives in order to achieve an efficient pooling of the resources for the benefit of all the countries involved. Every effort and imaginative solution has to be found to reduce the negative impact of the brain drain and brain unemployment (Ernst & Young, 2006).

The development and support of new entrepreneurs able and willing to capture the new opportunities offered by the biotechnologies must take place. It is the responsibility of the governments and their external assistance counterparts to create and support the appropriate measures for entrepreneurial involvement in biotechnology research and development. In a context of scarcity of resources, it is important that the research institutions and the academic institutions take the necessary steps to identify the most relevant products for the largest population. In their process to define the policy framework and the accompanying measures, the officials of the government should favour a participatory and dynamic process for priority delineation and for the conversion of scientific results into industrial use. The supply-led type entry into biotechnology has been the most common in developing countries and the private sector involvement has generally been very low. With the likely influence of the many on-going structural adjustment programs in developing countries and other trends toward liberalization, there seems to be more interest for an industry and a market-led type entry (Hidalgo and Monge, 1989).

Limitations to the Extension of Biotechnology in Developing Countries; The reduced per capita purchasing power of the potential users of new products in most of the developing countries stands in contrast with the availability of very lucrative markets in the developed countries. The situation in developing countries prevents the large multinational companies as well as the small ones involved in biotechnology research from implementing research facilities or sub-contracting research works in these countries. In these countries, the emergence of an active private sector for the implementation of a sustainable research and development system based on entrepreneurship is still very slow. The development of business linkages between developed and developing countries remains a difficult and challenging task. The absence in most of the developing countries of the necessary policy framework and the accompanying measures and regulations to promote biotechnology research and development is an area that limits the transfer of technology and business linkages. The shortage of well-trained and experienced scientists is felt across the developing world. The high costs associated with biotechnology research, the lack of venture capital or public funding to support the development of the appropriate infrastructure, and the operating costs of the research itself in the developing countries are major limitations (Rath and Lealess, 2000).

Suggestions for Better Benefits to the Developing Countries; The development of a critical mass of motivated scientists is a crucial element in all the countries. More resources from the development assistance agencies should be devoted not only to the training of these scientists but also to the building of appropriate physical environments where they can execute their research works. The development and support of new entrepreneurs able and willing to capture the new opportunities offered by the biotechnologies must take place. In a context of scarcity of resources, it is important that the research institutions and the academic institutions take the necessary steps to identify the most relevant products for the largest population. The external assistance programs should devote more resources to biotechnology for developing countries. Given the importance of the issues at stake and the complexity of the problems confronting the development of biotechnology in the developing countries, it was the panel opinion that IDRC should keep open the possibility of assembling a more permanent small group of experts to help reflect on how IDRC and other similar bodies could adjust their policies and programs to let the developing country populations, particularly the poor, access some of the benefits of the new biotechnology (McTaggart *et al.*, 2012).

CONCLUSION

Biotechnology has the potential to modify and improve the economic and social conditions of the populations living in the developing world. In the long run, it will create a new worldwide "revolution" in agriculture. The shortage of well-trained and experienced scientists is felt across the developing world. Successful scientists are often those who have adopted an aggressive entrepreneurial approach to obtain the resources necessary to achieve scientific

results. It is clear that there is a tremendous gap between the human capital in the development of products for the wealthiest people and the human capital provided/available for development of products for the poor in developing countries.

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