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Commercialization of Research Output for National Development: The Role of Technology Incubators in Nigeria

Ndagi Abdulmalik
Department of Business Administration, Faculty of Management and Social Sciences, Ibrahim Badamasi Babangida University, Lapai Niger State, Nigeria

Abstract

Commercialization is a process that converts intellectual property into marketable products and services, this process requires different skills, funding, team and market analysis as compared to non-technology businesses. Commercialization according to Dehghani (2015). It is a process through which knowledge and technology are transferred from universities and research centers to industries and new businesses. It is a complex process influenced by a variety of factors such as infrastructure, technological, social, political, and historical. These factors may either facilitate or impede the commercialization cycle. The successful commercialization of research output to a large extend depend on the successful identification of market demand and capacity for effective and efficient science and technological research output that can stand test of time vis-a-viz benefit to mankind. Commercialization of research output for national development provides the basis for knowledge-based economic development, economic prosperity and scientific and technological growth. Commercializing research output proposes directions for national development and integration accordingly, provides a catalyst to the knowledge-based economic development of countries. Commercialization is however, not a straightforward process; as many challenges must be overcome. It has been shown that new knowledge from universities must penetrate what is known as the knowledge filter in order to contribute to innovation, competitiveness and ultimately economic growth. The knowledge filter is defined as the barrier or gap between the investment in new knowledge and its commercialization and has been associated with bureaucratic red tape and illogical government regulation. Traditionally, commercializing R&D outputs is meant to enhance competitiveness and capability of the NIS by promoting indigenous technologies resulting from R&D activities undertaken by tertiary institutions, research institutions/Centres, industry, individual researchers, inventors and traditional knowledge. In the African context, Nigeria inclusive, university research capacity appears to be very limited, taking into account regional and country variations. Research capacity, defined by Volmink and Dare (2005), as comprising the institutional and regulatory frameworks, infrastructure, investment, and sufficiently skilled people to conduct and publish research, varies greatly across the continent. Commercialization models were appraised and recommended accordingly while the enormous challenges of commercialization in Nigeria were also presented as follows; Funding of R&D in Nigeria has largely been by the federal government through the yearly budgetary allocation thus resulting in poorly funded institutions, There is weak and unorganized institutional framework to midwife and nurture linkages between university and industry, Lack of adequate publicity for Intellectual Property Right in Nigeria etc. the recommendations include amongst the following; National research Fund, National Risk fund, National Innovation fund, establishing and Strengthening of IPTTO, Monitoring and Evaluation of universities specific set targets on IP, Capacity-Building in Relevant Skills and Policy Development, Lack of entrepreneurial culture by faculty members, establishment and Management of university science parks and technology incubators etc.

Keywords: *Commercialization, Research Output, Science Parks, Incubators, Nigeria.*

Corresponding Author: Ndagi Abdulmalik

Background to the Study

Commercialization is a process that converts intellectual property into marketable products and services, this process requires different skills, funding, and team and market analysis as compared to non-technology businesses. According to Infodev (2013). Technology commercialization is the process of taking a piece of technology, research and development results, invention or scientific intellectual property (IP) often, but not necessarily the result of university or similar research and turning it into a commercially viable product or service that is demanded by the market. Infodev therefore concluded that Technology commercialization is often known as IP Commercialization or Technology Transfer.

The successful commercialization of research output to a large extend depend on the successful identification of market demand and capacity for effective and efficient science and technological research output that can stand test of time vis-a-viz benefit to mankind. Commercialization of research output for national development provides the basis for knowledge-based economic development, economic prosperity and scientific and technological growth. These are achievable through strategic systematic and integrated approach to valuing research and its findings as well as achieving an effective and efficient interaction of academia – industry and government which are the strategic components for national innovation system. One major cause of fast-growing and improved technology in industrialized countries according to Dehghani (2015) is a good deal of attention devoted to commercialization of research results conducted in such countries. He further posits that, inabilities to commercialize, apply research findings in new products and processes, and introduce them to market are major drawbacks of developing countries.

Commercialization is the process of introducing new products or services to the general market. It takes into account production distribution, marketing sales and customer support required to achieve the commercial success of the new product or services.it is assumed that to build a successful profitable business, creative ideas should be commercialized. As conceptualized in several literatures, commercialization is a complex non-linear cycle which necessitates that all relevant stakeholders effectively and efficiently perform their responsibilities.

Commercializing research output proposes directions for national development and integration accordingly, provides a catalyst to the knowledge-based economic development of countries. It also brings about economic prosperity and scientific growth which are critical starting points for countries to become a source of knowledge production and knowledge data bank. Such achievement is feasible through valuing research and its findings as well as achieving an effective interaction of components relevant to national innovation system. Commercialization process has some key features according to Reamer et.al (2003). Firstly, they assert that it is a cycle whereby a

given input passes through a series of stages to reach a specific output and in every stage some value is added to it. However, the chain of stages gives the product more added value than the sum of added values at all stages. Secondly, this process, in an attempt to help investors reap benefits, exploits all possible potentials including labor force, organizational structure, rules and regulations, technology, and whatever which deserves to be considered potential. Thirdly, technology commercialization is a necessary part of innovation. If technological innovation is assumed to range from idea generation to initial market entry, there will be no innovation and, thus, no technology without commercialization.

Literature Review

Commercialization according to Dehghani (2015).It is a process through which knowledge and technology are transferred from universities and research centers to industries and new businesses. It is a complex process influenced by a variety of factors such as infrastructure, technological, social, political, and historical. These factors may either facilitate or impede the commercialization cycle. He further posit that it is one of the most controversial issues that is the reason number of companies and countries give first priority to this issue and allocate their attention among a number of activities. However, even within industrial countries there are some barriers to commercialization such as financial problems, inefficiency of organizational bureaucracy, paucity of research on the influence of organizational strategies and understanding necessary interaction between research teams, lack of mass production, evaluation of research findings, implementation of reforms, and product optimization which are being gradually eliminated. Lack of financial resources devoted to commercialization which supposes to be a facilitator then leads to poor access to commercialization guidelines and application of research findings.

Commercialization of research results according to Ogunwusi and Ibrahim (2014). has become the new catch-cry in most advanced economies as they embrace innovation as a key driver of economic policy. The transfer, exploitation and commercialization of public research results have become a critical area of science, technology and innovation. The knowledge and research generated by public research system is diffused through a variety of channels among which are the mobility of academic staff, scientific publications, conferences, contract research with industry and the licensing of university inventions. Effective commercialization of research results in any nation will depend on rapid technological innovation, effective strategic management of knowledge and a clear focus in value added goods, services and industries.

Technology commercialization according to Infodev (2013) further said, is not the same as technology adoption hence, Technology commercialization is the process of transforming innovative technologies developed by universities, companies and inventors into commercially viable products and services that are in market demand,

whereas technology adoption is the normal cycle of acceptance of that technology by the market; by innovators, early adopters, early majority, late majority and laggards. Technology commercialization remains a risky, difficult and expensive process that needs to be addressed cautiously by a business incubator manager to successfully commercialize it.

Incubation is a natural partner to Technology Transfer Offices which often exist within a university or research center to help the research institution benefit from the IP it has created. Some TTOs include an incubation function but many will partner with external incubators. There are many common mistakes that commercialization professionals try to avoid, keep expectations within the boundaries of what is likely; don't be over confidence.

The university is a key element of the triple helix of innovation system both as a human capital provider and a seed-bed of new firms (Etzkowitz *et al*., 2000; Laredo and Mustar, 2001). To realize the benefits of knowledge and to receive returns from these investments,(research and Development findings) the resulting innovations or intentions must be sold, or commercialized (Meyers, 2009).Knowledge-based economy is depended on high investment in education and training, research and development (R&D), the presence of high-quality scientific research institutions, extensive relationships between governments, academia, and industry and the protection of intellectual property (Lowe, 2005; World Economic Forum, 2010/2011).

knowledge, technology, innovation and human capital are generally understood as central and key drivers for generating sustainable economic growth and competitiveness and they represent key explanations for significant and persistent divergences in economic growth and development between countries and regions not natural resources or exports based on cheap labour (Howells, 2005).

Commercialization is however, not a straightforward process; as many challenges must be overcome (Al Natsheh *et al*., 2015). It has been shown that new knowledge from universities must penetrate what is known as the knowledge filterin order to contribute to innovation, competitiveness and ultimately economic growth (Audretsch *et al*., 2006; Acs *et al*., 2010). The knowledge filter is defined as the barrier or gap between the investment in new knowledge and its commercialization (Al Natsheh *et al*., 2015); and has been associated with bureaucratic red tape and illogical government regulation (Audretsch, 2014). knowledge flows from universities (and research institutions) are much more diverse than they had been in the past, with publications and paper presentations at meetings being just two among a wide array of transfer mechanisms. Commercialization as a new form of technology transfer is becoming increasingly common which can be either directly, by nurturing academic entrepreneurship in incubation centres, or indirectly, by transferring knowledge and sharing expertise through consulting, joint

research ventures, patenting, licensing of intellectual property, contract research or forming start-up companies (Cohen *et al*., 2002). Traditionally, teaching and research have been the university`s main roles. However, commercialization of research results or entrepreneurial science also referred to as, technology/knowledge transfer, third stream third mission or engagement, has emerged as an additional role for universities as stimulators and facilitators of knowledge transfer (Perkmann *et al*., 2012). The third stream is about the interactions between universities, industry and the rest of society, and can be said to be the stimulation and direct application and exploitation of knowledge for the benefit of the social, cultural and economic development of society - *i.e*., community outreach (Molas-Gallart *et al*., 2002), making technology available to end-users (Tahvanainen and Nikulainen, 2010).Studies into the third mission of academic institution highlight that universities have matured in their approach to technology transfer, in what appears to be a more iterative and cyclical process of innovation diffusion, such that the double-helix character of DNA has been metaphorically adapted to describe the university-industry-government relationship, this time as a triple-helixto encourage development (Leydesdorff and Etzkowitz, 1996; Etzkowitz and Leydesdorff 2000).

The intertwined (overlapping) relationship of the triple-helix suggests that the movement of knowledge is not necessarily one way but rather cycles in and out (iterative) of each triple-helix partner depending on the nature of the technology and the sources of intellectual capital best suited to its movement (Powers and Campbell, 2011). In this sense universities (and independent research institutions) are not only a source of knowledge, but are also active participants in the organization, development and commercialization of innovation. More recently, there has been the inclusion of the the market/society as a fourth strand to the helix, leading to a Quadruple helix model (Carayannis and Campbell 2010). This makes a perfect sense since the desired output of the triple helix activity is new and innovative products and services, which have to relate to the market and society in order to generate jobs and wealth and ultimately achieve greater competitiveness (Carayannis and Campbell 2010).

Bayh-Dole Act and commercialization of university research

In order to penetrate a formidable knowledge filter and facilitate university entrepreneurship and technology transfer from the university, the U.S. Congress attempted to remove potential obstacles to university technology transfer and commercialization by passing the University and Small Business Patent Procedures Act of 1980, more commonly known as the Bayh-Dole Act, 1980 (Link *et al*., 2007; Kenney and Patton 2009). This Act established the legal framework for commercializing the research that is developed within university settings by transferring the ownership of intellectual property (IP) from the publicly funded granting agencies to the universities. The logic was to give the universities incentives to support and build an infrastructure for the commercialization of research, with licensing preferences going to small businesses and

industries within the United States (Link *et al*., 2007; Kenney and Patton 2009).This policy change stressed the expectations that the universities could contribute more directly to industrial development (Stevens, 2004). It played a critical role in rejuvenating the entire U.S. economic system, transforming it from a manufacturing base to an innovation base (Loise and Stevens, 2010). Prior to the Bayh-Dole Act, the United States government owned and managed intellectual property developed at academic institutions as the result of federal funds, hence, nobody could exploit the outputs of publicly funded research without tedious negotiations with a federal agency concerned (Kesselheim and Rajkumar, 2011). In view of this arrangement, patent protection and licensing of technology was rarely pursued (Kirschenbaum, 2002). Worse, companies found it nearly impossible to acquire exclusive rights to a government owned patent, and without that, few firms were willing to invest millions more of their own money to turn a basic research idea into a marketable product (Audretsch, 2014). Bayh-Dole Act 1980, led to a massive increase in funding to universities by venture capitalists (Valentine and Claasen, 2002), resulting in a rapid rise in commercial knowledge transfer from university to industry (Jensen and Thursby, 2001), through mechanisms such as, partnerships, licensing agreement and university start-ups, also known as spin-offs or Spin-outs (Banal-Estañol and Macho-Stadler, 2010).

A commercialization survey by the Association of University Technology Managers (AUTM – the technology transfer profession interest organization) among United States-based institutions showed that due to the Act, the number of patents granted to US universities increased from 589 in 1985 to more than 3200 in 2006 (AUTM, 2007). In addition, there were 16000 patent applications and 553 spin-off establishments in the same year. Start-ups are new firms created to exploit commercially some knowledge, technology, or research results developed within a university (Pirnay*et al*., 2003).Research has pointed out that there are two essential determinants explaining the process of knowledge transfer from universities to industry namely: (1) the linkages between researchers and research users, such as private firms and government agencies; and (2) the focus of the research projects on users' needs *i.e*., research that is-fit-for purpose (Landry *et al*., 2007). As a result, the United States has become very advanced in technology transfer and commercialization (TT & C) because of this Act, which has been in effect for more than 30 years (Loise and Stevens, 2010). The subsequent success of Bayh-Dole Act as a catalyst in the US for bringing new research findings to the marketplace inspired legislative changes in many OECD and beyond countries such as Germany, Denmark, Japan, Canada, India, the United Kingdom and Singapore to enact similar laws to this Act (Slaughter and Leslie, 1997; OECD, 2003;Mowery and Sampat, 2005).

Commercialization of research and development output in Nigeria according to NOTAP (2018). Depends heavily on its ability to acquire and apply technology indigenously to produce goods, processes, devices and provide services. To achieve this, a well-focused

National Innovation System (NIS) is necessary in which technology acquisition is well matched to the needs of the market and industry. The Nigerian NIS is composed of ministries, departments and agencies, tertiary institutions, research institutions/Centres, financial institutions, the industries and civil society organization.

Traditionally, commercializing R&D outputs is meant to enhance competitiveness and capability of the NIS by promoting indigenous technologies resulting from R&D activities undertaken by tertiary institutions, research institutions/Centres, industry, individual researchers, inventors and traditional knowledge.

In the African context, Nigeria inclusive, university research capacity appears to be very limited, taking into account regional and country variations. Research capacity, defined by Volmink and Dare (2005), as comprising the institutional and regulatory frameworks, infrastructure, investment, and sufficiently skilled people to conduct and publish research, varies greatly across the continent. Indeed, a study by the RAND Corporation revealed that, with the exception of South Africa, Egypt, Mauritius, and Benin, African countries were part of a group of scientific laggards (RAND Corporation, 2001). Furthermore, a 2007 report recognized that African higher education lacks capacity not only at the system and institutional levels, but also at the level of individual academics (Jones et. al. 2007). The research grant lying idle at Tetfund is Nigeria example according to (Bogoro, 2015) where he confirmed availability of research fund at tetfund totaling about four billion naira and only 20% have been accessed by university researchers over the years.

Research Institutions in Nigeria

Research according to Ogunwusi and Ibrahim (2014) is a means of demonstrating one's ability and capability in solving an identified problem and it is an important pointer to the national technological capability. One of the major roles of research is breeding industrialization which brings about jobs and wealth creation, arrests social menace and assists in curbing rural urban migration. The history of Research and Development in Nigeria can be traced to the establishment of a National Council for Scientific and Industrial Research (NCSIR) in 1964, following an international conference on the organization of Research and Training in Africa (FMST, 2010). According to Yusuf (2012), the Council's mandate was narrow and as such had structural weakness which made its function ineffective and inefficient. As a result, with assistance of UNESCO experts, four research Councils were established after the Civil war in 1970. These were:

1. Agricultural Research Council of Nigeria (ARCN)
2. Medical Research Council of Nigeria (MRCN)
3. Natural Sciences Research Council of Nigeria (NSRCN)
4. Industrial Research Council of Nigeria (IRCN)

In 1986, the first National Policy on Science and Technology (S&T) was launched (Yusuf, 2012). The policy identified that S&T-related activities in the country had been carried out without well-defined national direction. The public universities, research institutes and research outfits in private sector companies are expected to be drivers of research and development and home grown technologies. Also, R&D are expected to lead to home grown industries and power multinational companies within the country. However, since 1964 till now, despite the endowment of the nation with a large population and abundant natural resources, Nigeria is yet to advance economically. Up till now, the nation does not have any globally branded product, multinational company, technical and managerial expertise or worldwide range of Intellectual Property Rights exploited globally that emanated from its indigenous knowledge and industrial efforts (Bindir and Tandama, 2013).

Abubakar, (2019) state that the newly approved universities were joining the largest university system in Africa in terms of number and enrolment, comprising of forty three (43) federal universities, forty eight (48) State universities and seventy nine private universities, translating into one hundred and seventy (170) universities in Nigeria. This shows that educational and knowledge infrastructure are abound in the country with also about 125 polytechnics,98 colleges of education, over 300 institutions composed of research institutes, innovation agencies and policy implementation departments, multinational companies, large pool of skilled labour force including a sizeable number of diaspora, making up a total of approximately 693 institutions directly or indirectly involved in research yet Nigeria economy is still technologically weak with a very high national poverty incidence that implies that over 100 million Nigerians are living below the poverty line.

Siyanbola et.al. (2012) said there are a total of seventeen (17) agencies that constitute the Federal Ministry of Science and Technology; Fourteen (14) of these agencies are charged directly with the mandate to conduct R&D . The other three have mandates for policy research and capacity building in management of technology, intellectual property rights, and technology business incubation. National Agency for Science and Engineering infrastructure (NASENI) is charged with research in capital goods, production and reverse engineering; Federal Institute of Research (FIIRO) is mandated to accelerate industrialization in Nigeria; Sheda Science and Technology Complex (SHESTCO) has the mandate to develop research results for application in areasof agriculture, health, industry and environment; National Space Research & Development Agency (NARSDA) is vested with research in space and development. Promoting the development and utilization of Nigeria's industrial raw material is the responsibility of Raw Materials Research and Development Council (RMRDC); Nigerian Building andRoad Research Institute (NIBBRI) is to ensure improvement in the quality of life of Nigerians in the areas of affordable housing; Nigerian Natural Medicine Development Agency(NNMDA) will do research, develop collate, document and promote the nation's

natural medicine; Nigerian Leather and Science Technology (NILEST) is a Centre for development in the areas of Chemical and Leather technology. National Research Institute for Chemical Technology (NARICT) develops the technologies required by the chemical industry and also undertakes R&D work in areas of agriculture, mineral and other raw material conversion to chemicals; Project Development Institute (PRODA) has part of his mandate to develop the technologies required by the power equipment industry; National Biotechnology Development Agency (NABDA) coordinates, promotes and regulates the development of biotechnology in Nigeria. Nigeria Institute for Trypanosomiasis Research (NITR) is to conduct R&Dfor the control and elimination of Trypanosomiasis and its vectors; The Nigerian Institute of science laboratory technology (NISLT) conducts research in all the areas of Science Laboratory Technology; Nigeria Atomic Energy Commission (NAEC) coordinates R&D activities for capacity building and infrastructure development in Nuclear technology. In charge of Intellectual property and research industry linkages are the National Office of Technology Acquisition and Promotion (NOTAP). National Board for Technology Incubation (NBTI) provides institutional in frastructure and mechanism for the development and commercialization of R&D outputs and inventions. National Centre for Technology Management (NACETEM) is mandated to provide knowledge support for the STI system in Nigeria through capacity building in management of technology, STI policy research and consultancy.

Another reason for the American success in commercializing public science is the substantial licensing income that universities such as Stamford, Colombia, MIT and the University of Florida have earned from patenting their inventions. The causes of failure by Nigerian scientists could be attributed to a wide range of factors including a lack of entrepreneurial spirit among scientists, barrier to the ability of public sector scientists to move to the private sector on a temporal basis to develop their discoveries and to poor Intellectual Property Right of university inventions. Currently in Nigeria, existing approaches for linking research with private enterprise take the form of research products fairs, experimental incubator models and incoherent outreach approaches (Binder and Tandama, 2013).

The most important implicit factors limiting the development of a virile Science, Technology and Innovation and consequently, technology development and transfer in Nigeria is funding of research and development activities. Technology transfer include a set of activities starting with investment in R&D, the R&D performance, decision on how to handle the intellectual property to demonstrate technology and commercialization which brings the products to the market. In this new economic order, developing nations can no longer compete based on their natural resource endowments and locational advantages. (Ogunwusi & Ibrahim 2014). In Nigeria, the Intellectual Property Right (IPRs) of innovators and industrialists are governed by Patent and Design Act cap 344 of 1990, Trademarks Act Cap 436 of 1990 and Copyright Act of 1998 (Ukpabi,

2009).Managing Intellectual Property Rights and Technology transfer issues in Nigeria has been part of the core mandates of the National Office for Technology Acquisition and Promotion (NOTAP). To ensure a link between R&D activities carried out in the country and the market, and facilitate process of commercialization, NOTAP has established over 43 Intellectual Property and Technology Transfer Offices (IPTTO's) in tertiary institutions across Nigeria and assist innovators to prepare and file applications for property rights. Nevertheless the number of applications for rights protection filed by public RI's between 1999 and May 2012 was lower than those filled by private innovators, indicating that the public RI's are less interested in rights protection and consequently commercial exploitation of their results (Siyanbola et al, 2012).Presently, over 100 commercialisable R&D outcomes in the areas of Agriculture , Industry, Engineering, and Health have been successfully produced by agencies under the Federal Ministry of Science and Technology in Nigeria. Less than 2% of R&D in Nigeria have been commercialised. In view of this, Siyanbola etal (2012) recommended a change in commercialization strategy in Nigeria through adoption of new strategic approach.

Commercialization Models

In Organization for Economic Cooperation and Development (OECD) countries, knowledge and research generated by public research system is diffused through a variety of channels. These include mobility of academic staff, scientific publications, conferences, contract research with industry and licensing of university inventions. Much of the policy forms in OECD countries have been centered on promoting knowledge transfer via a dual, but rather linear model of commercialization. This model is characterized by several push forces whereby universities and public research institutes transfer academic inventions via the sale, transfer or licensing of intellectual property, often on an exclusive basis to existing firms or new ventures. The converse of the model is a demand-pull model based on contract research or collaborative research and development whereby universities and public research institutes are solicited by industrial actors to find solution to production and innovation problems (OECD, 2012).

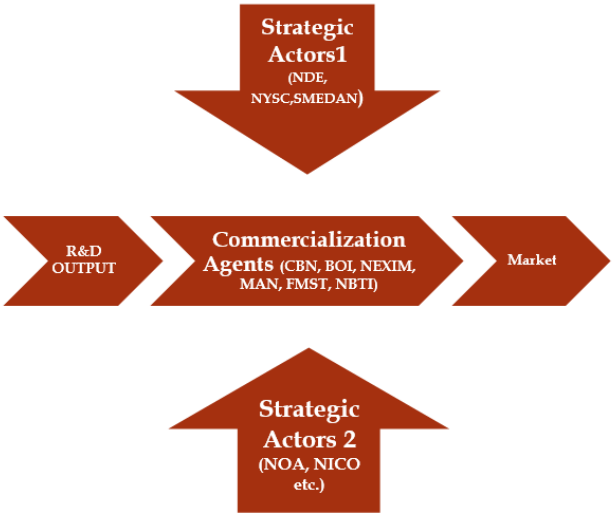

Fig. 1: Commercialization Model One: Developed and Recommended by Siyanbola et.al (2013) for FMST.

1. R&D Output: Database of R&D from universities/HEIs, research institutes/centers, private company.
2. Commercialization Agents: These are group of experts who connects the R&D outputs with the market (CBN, BOI, NEXIM, MAN, FMST, NBTI etc.)
3. Strategic Actors1: These comprise of actors that make use of R&D outputs and process them into finished products for the market.
4. Strategic Actors2: These are actors responsible for sensitization and advocacy on patronizing goods produced in Nigeria. (NOA, NICO etc.)
5. Market: The whole essence of the activities starting from the laboratories through the other actors in the commercialization process.

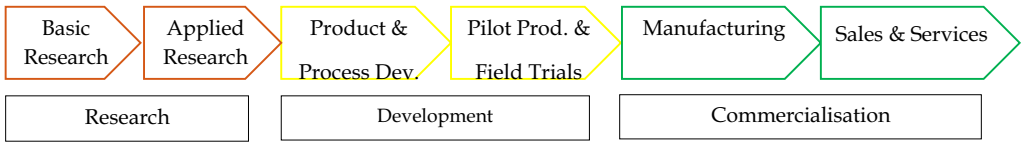

Fig. 2: Commercialization Model Two: Developed by Otto Lin of Taiwan University in 2001 and been used by Hong Kong, china, Taiwan.

1. Basic Research: These are basic in nature as they failed to have specific focus mostly conducted by undergraduates.
2. Applied Research: These are market driven, need focused development drive research usually conducted by advance researchers and market demand.
3. Product and process Development: These involves the design and model phase for the product and process.
4. Pilot production, field trial and test running: This is to ascertain we are on cause to full manufacturing.

5. Manufacturing: Commence full scale commercial production according to specification and standards.
6. Sales & Services: Marketing expert to handle marketing for sales and after sales service to ensure appropriate feedback for correction.

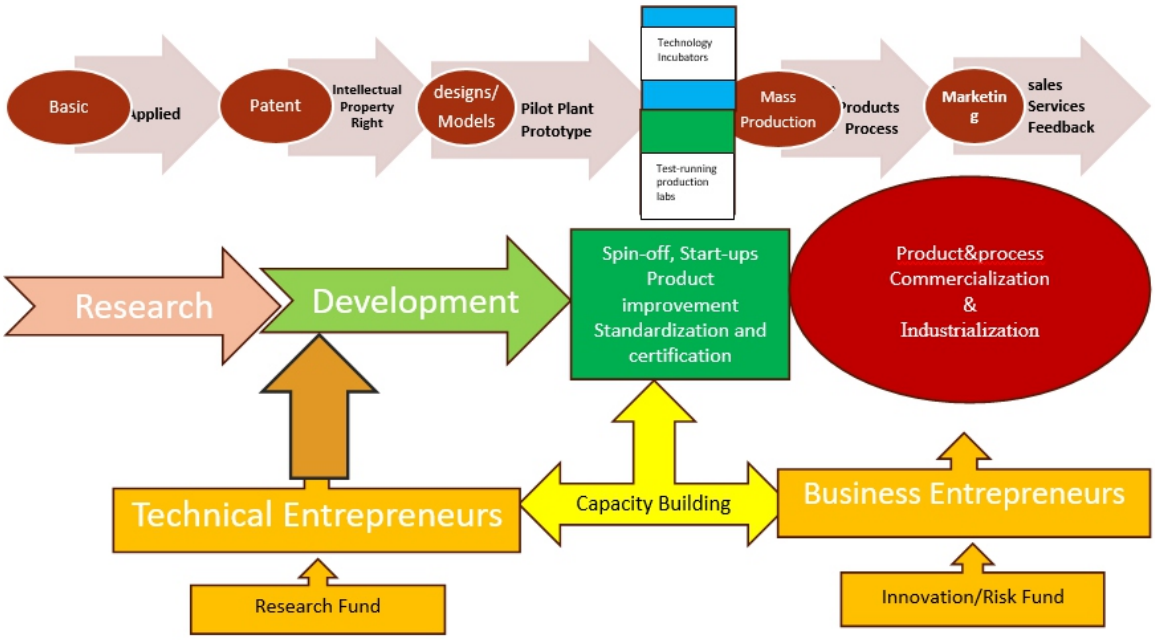

Fig. 3: Commercialization Model Three: Developed and Recommended by Ndagi (2017) for NBTI.

R&D output and Commercialization Challenges in Nigeria

1. Funding of R&D activities in Nigeria according to Siyanbola et. al. (2013). has largely been by the federal government through the yearly budgetary allocation thus resulting in poorly funded institutions. The highest proportions of science and technology (S&T) activities in Nigeria are carried out by public institutions which invariably demand that it should be given more priority in the national budget. The limited funding of R&D activities in Nigeria, in practical terms, is a reflection of low appreciation of the benefits of R&D to national development. This stands in sharp contrast to government determination to leapfrog development through the application of science and technology. Although there are funding support for projects and R&D activities from international organizations, however, much investment and support is still needed in this sector

2. Lack of adequate publicity for Intellectual Property Right in Nigeria; Intellectual Property Rights (IPRs) of innovators and industrialists in Nigeria are generally governed by Patent and Design Act Cap 344 of 1990, Trademarks Act Cap 436 of 1990 and Copyright Act of 1998 [7]. Managing Intellectual Property Rights and technology transfer issues in Nigeria has been part of the core mandates of the National Office for Technology

Acquisition and Promotion (NOTAP). This agency has been operating in compliance with the Trade Related Aspects of Intellectual Property Rights (TRIPS) of the World Trade Organization (WTO) which set the minimum acceptable standard for member countries. To ensure a link between R&D activities carried out in the country and the market, and facilitate the process of commercialisation NOTAP has established over four-three (43) Intellectual Property and Technology Transfer Offices (IPTTOs) in tertiary institutions across Nigeria and assists innovators to prepare and file applications for property rights.

3. The Nigerian STI system overtly depends on government for nearly all its requirements. According to Bindir & Tandama (2013). As a result, a number of implicit and explicit factors influence the performance of Science and Technology Innovation system in Nigeria. Implicit factors such as state of art infrastructure to carry out meaningful research work on competitive basis is absent in most of the organizations as most of the universities and research institutes are not adequately equipped with modern facilities

4. The challenges of R&D output commercialization according to Ogunwusi & Ibrahim (2014). is compounded by lack of steady power and water supply. The need for adequate information on global best practices, sources of grants and the information on current status of development in several disciplines are not available to most of the research scientists. In most universities and research institutes, latest relevant journals are scarce and most researchers are left with the information obtainable on the internet. Other important implicit factors such as training of personnel and funding are abysmally inadequate. In addition, the existing R&D reward systems are also clearly inadequate. The explicit factors germane to the successful performance of STI system which include commercialization of R&D results, linkages, quality assurance, Intellectual Property Rights (IPRs) system, entrepreneurship, investment, investors' confidence and marketing strategy are in most cases unorganized and inadequate in public R&D organizations and the universities. The most important implicit factors limiting the development of a virile Science, Technology and Innovation and consequently, technology development and transfer in Nigeria is funding of research and development activities. Technology transfer typically include a set of activities starting with investment in R&D, the actual R&D performance, decision on how to handle the intellectual property to demonstrate technology and commercialization which brings the products to the market.

5. Another significant challenge militating against successful technology transfer from laboratory to the market is the little or no linkage that exists between research institutes, universities and the industry. The opportunity for a country to initiate, maintain and sustain competitive advantage through innovation rests on its ability to create and advance synergy. Though, the number of universities and research institutes in Nigeria is high, the anticipated commercialization has failed mainly due to the lack of connectivity between industry and the academia. This is due to the fact that commercialization of R&D results has not been traditionally, a high priority of universities. The public universities in Nigeria are funded directly from the national budget. Private sector funding of R&D in Nigeria is lagging. (Ogunwusi & Ibrahim 2014).

6. There is weak and unorganized institutional framework to midwife and nurture linkages between university and industry which leads to inadequate and in some cases non-existing strategic partnership for commercialisation and innovation networking of the universities, business community and the government. Essentially, there is poor correspondence between expectations/needs of the private sector and the research priorities in the universities and specialized research institutions.

7. The causes of failure by Nigerian scientists could be attributed to a wide range of factors including a lack of entrepreneurial spirit among scientists, barrier to the ability of public sector scientists to move to the private sector on a temporal basis to develop their discoveries and to poor Intellectual Property Right of university inventions. Currently in Nigeria, existing approaches for linking research with private enterprise take the form of research products fairs, experimental incubator models and incoherent outreach approaches. On the other hand, the organized private sector, including industrialists, business people and agriculturists, hardly shows confidence orstake in the existing linkage systems. Hence, the solutions to local industry problems are often sought without recourse to the skills, capabilities and opportunities within the university system (Bindir and Tandama, 2013).

8. The challenges to Commercialization of University research in Kenya according to Ayisi et al. (2016).are numerus among which are; Only few members of university staff are engaged in research and development this is due to too much teaching at the expense of research. Staff promotion policies demand prolific publications and dissemination of research results at conferences thus losing the patentability of inventions this requires need to move from publish or perish to innovate or perish.

9. A recent report on the state of university-industry linkages in Africa revealed the following relevant findings that serve as a cautionary warning (AAU & AUCC 2012):

a) University research output is limited by the low percentage of academic staff with PhD training and qualifications, and brain drain of qualified scientists;
b) Many African universities have attempted to foster linkages with firms through the creation of offices and staff positions in charge of such affairs. However, such offices lack the material resources and expertise to handle industry partnerships and technology transfer effectively;
c) There is a low number of science parks and technology incubators in academic institutions. Only a small percentage of universities surveyed reported being involved in managing science parks, technology incubators and engaging in technology transfer;
d) The study suggests that support for establishing and managing technology incubators and science parks would respond to the needs and priorities of African universities.

Concept of Technology Incubation

There are several definitions and approaches to business and technology incubation. Conceptually, 'incubation' is a more diligent and planned process than clustering or `co-location' and therefore needs careful attention to the problems of prospective occupants, extending well beyond providing infrastructure and office services (Adelowo, Olaopap and Siyanbola 2012; Kiridena, 2001). According to the National Business Incubation Association (NBIA), Business Incubation catalyses the process of starting and growing companies, providing entrepreneurs with the expertise, networks and tools they need to make their ventures successful. Incubation programmes diversify economies, commercialise technologies, create jobs and create wealth.

The term incubator, which is more widely known with the life-giving support to premature babies or phenomenon to enable them survive the critical early period of life, is what has been adapted to economic development and regeneration. Therefore, economically, definition of Incubation/Incubators varies with their services, their organizational structure and in the types of clients they serve. Technology Incubation has different goals which include job creation, new venture creation, wealth creation, value addition to clients' products, process and services and transferring technology from universities and major corporations to entrepreneurs/enterprises (Smilor and Gill, 1986). According to Lalkaka (2000), business incubation is a means by which visions of new businesses are turned into reality with reduced risks. Incubators aspire to have a positive impact on a community's economic health, by maximizing the success of emerging companies (Cassim, 2001). Business incubators have proved effective in many parts of the world. According to Rice and Matthews (1995), only 10 business incubators existed in the United States in 1980. There were nearly 500 by 1995, and a new incubator has been opening every week. The technology incubators generally focus on nurturing technology-intensive enterprises and knowledge-based ventures.

The technology incubation system (TIS) is variously represented by entities such as Techno-polis, Science Parks, Research Parks, Technology Parks, Technology and/or Business Incubators. These entities operate as separate organisations but are mostly integrated with other players in the innovation system. The terms Science Parks, Research Parks and Technology Parks as well as Technology Incubators (TIs), Technology Innovation Centres (TICs) and Technology Business Incubators (TBIs) are used interchangeably in many countries depending on the level and type of interaction between R&D community, venture funding and industry.

Relevant research thus comes from countries in Europe and North America. Several studies analyse the aims, structures and spatial impact of technology incubation centres and similar initiatives. In some countries, lengthy and comprehensive impact evaluations have already been conducted. With respect to technology incubation centres, Germany, United Kingdom, Sweden and the whole of the European Union (European Commission, 1996; Massey et al. 1992;) may still be the best researched countries. More or less comprehensive evaluations are found in other countries such as the USA (Luger and Goldstein, 1991).

In this paper, the term technology incubator is taken to mean a controlled environment- physical or virtual- that cares, and helps new ventures at an early stage until they are able to be self-sustained through traditional means while technology incubation apply generically to all the organizational forms for promoting technology-oriented SMEs respectively. The organizational format of technology incubations also varies and could generally be categorized as public or not-for-profit incubators, private incubators, academic-related incubators and public/private incubators, which are referred to as hybrid in most literatures. Also, technology incubations may thus have a wide range of goals and objectives giving rise to different forms of incubators specializing in accessing diverse resources. In the last two decades, African countries have embarked on establishment of technology parks and incubators to fast-track and sustain economic growth, creating jobs for fresh graduates and transition into the knowledge economy through commercialisation of research results.

The International Association of Science Parks (IASP) considers that the term "Science Park" could include Technology Park, Technopole and Research Park (Link and Scott, 2011), and defines it as an organization managed by specialized professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and competitiveness of its associated businesses and knowledge-based institutions (International Association of Science Parks, 2014).

On the-other-hand IASP defines an incubator as an organization designed to accelerate the growth and success of entrepreneurial companies through an array of business support resources and services that could include physical space, capital, coaching, common services and networking connections (IASP, 2014). Many technology parks explicitly incorporate business incubators into their developments to provide facilities for the nurturing of firms at all stages of their business and technological life cycles, as they are a key mechanism for technology transfer. They are seen as a mechanism to support and establish new businesses/start-up and fledging companies to promote job creation, economic development, innovation and high growth, by providing a wide variety of services that are typical to most starting ventures: physical space and infrastructure (office space, secretarial and administrative services), business consulting and training, funding applications (government and private), IP protection, technology transfer, and networking (Jamil *et al*., 2015). Incubator program gives a chance to projects that are unable to attract commercial investors in the initial stages of development.

Incubators are available in various types rendering a range of long and short-term assistance and they help in the establishment of new enterprise in one way or the other. Many of these provide only guidance, technical assistance and consulting to entrepreneurs and offer business development services. ICT incubators are major examples of these Incubators where clients access to appropriate rental space, shared basic business services and equipment. Few incubators assist only in developing new ideas and arrange for venture capital funding. Incubators are sometimes known as Business Accelerator as it accelerates start-ups by providing quick knowledge, support services and resources (Lewis, 2001).

Highly adaptable incubators have differing goals, including diversifying rural economies, providing employment for and increasing wealth of depressed inner cities, and transferring technology from universities and major corporations (Smilor and Gill, 1986). Incubator clients are at the forefront of developing new and innovative technologies – creating products and services that improve the quality of our lives in communities around the world.

Essentially, the incubation programme is to assist and support the transformation of selected, early stage businesses with high potentials, into self-sufficient, growing and profitable enterprises (Lewis, 2001). By reducing the risks during the early period of business formation, the incubation sustains the new enterprises that might otherwise fail due to lack of adequate support. In doing so, the incubation programme contributes to the economic growth by creating jobs and offering other socio-economic benefits. According to Adelowo et.al (2012), technology incubation programme can therefore be seen as an economic development tool designed to accelerate the success of high technology entrepreneurial enterprises through the provision of an array of technology business support resources and services in a controlled work environment.

Lewis (2001) sees technology incubation programme as an innovative system designed to assist entrepreneurs and inventors in the development of new technology -based firms. It seeks to link talents, technology, capital and know-how effectively, in order to accelerate the development of new businesses, and thus speeds the commercialization of technology. It is a facility that helps the early stage growth of technology-based enterprises by providing shared facilities such as space, office services, and business consulting services.

This concept, which constitutes a very potent economic development tool has generated great desire and has undergone extensive development in the USA and many other countries such as India, Japan, China, Korea, Israel, Germany, France etc. in the context of new global trend of engendering real sector development through small and medium scales businesses.

Technology incubation programme as a tool for economic development makes provision of job creation, employment opportunities targeting unemployed university graduates, retrenched public sector employees, retired research institution employees, retired private sector employees, and established industrialists desiring to expand or diversify their businesses (Lalkaka, 2000).

Promotion of small and medium scale development is yet another contribution of technology incubation programme on the economy, that is, it assists in incubating knowledge-based skilled and unskilled workers, start-ups into commercially viable products/services by providing specialists in various area of endeavors, skilled training, guidance, critical support services, such as invention and innovation, financing, laboratory, library, networking/ ICT, quality control workshop support services to all tenants or small and medium scale businesses at each centre, and a conducive environment (affordable, well-equipped workspace) to entrepreneurs.

Incubation programme was introduced to Africa in 1988 by United Nations Development Programme (UNDP) to test run the concept on pilot scheme in four (4) countries of Ivory coast, Nigeria, Equatorial Guinea and Zimbabwe. In 2012, the incubation programmes has spread across Africa with approximately about one hundred incubation centers. Nigeria has about forty (40) incubation centers, South Africa with about thirty-six (36) while the rest of other countries house the remaining twenty (20).Since 1988 with feasibility study for the establishment of incubator pilot centers at Lagos, Kano and Abato ascertain the viability of Technology Incubation in these commercial cities. TIC Lagos was in 1993, TIC Kano was in 1994 and TIC Aba was in 1995. The success of these three pilot centers facilitated the establishment of TIC Minna, Nnewi and Calabar in 1998. Meanwhile, by 2005 there were seventeen (17) incubation centers in Nigeria but as at 2012 there are about forty (40) incubation centers in the country with about two hundred and eighty-seven (287) entrepreneurs and six thousand two hundred (6,200) jobs created. (NBTI. Annual report 2013)

The Policy Thrust and objectives of Technology Incubation Programme

The policy thrust of the Technology Incubation Programme according to Federal Ministry of Science and Technology [FMST] (2005) is to pursue the commercialization of technologies and technical innovations using Technology Incubation as a tool in order to enhance the attainment of technological, industrial, social and economic competitiveness of the country and improve the quality of life of its citizens.

FMST (2005) explains that the vision of the programme is to make Nigeria a competitive nation through the commercialization of R&D results and other innovative efforts using technology incubation as a tool while the mission is to develop the necessary infrastructure to nurture technology starts-up to promote Nigeria's indigenous potential through value-added and technology-related activities and to create enabling environment for effective linkage amongst technology providers, entrepreneurs, and capital .

The larger objectives of our technology incubation programme according to FMST (2005) includes the following:

1. To impact practical and result-oriented training in several industrial trades. Special training programme will be introduced for rural artisans and vulnerable group of the society in collaboration with institutions of higher learning or research centers and other stakeholders located nearby.
2. To monitor closely the development of prototypes of machines, equipment and tools this could be passed on to the manufacturing units for commercial production.
3. To provide common facilities in such areas as testing, machining, castings, electroplating, quality control laboratories etc.
4. To encourage the production of machines and equipment, partly or fully as per market acceptability.
5. To develop testing and inspection of facilities for use by small scale units in collaboration with research centers.

6. To demonstrate R&D results in such critical areas as waste utilization, energy saving etc.
7. To help in ensuring that new ideas/products evolve into fruitful technical/manufacturing businesses using the abundantly available raw materials.
8. To help in solving specific problems for client entrepreneurs by continuously injecting innovation in materials processing.
9. To offer engineering services such as design testing, process/product performance monitoring and improvement, as well as training and general consultancy to client entrepreneurs.
10. To liaise with research centers and institutes in the design, development and production of improved tools for use by rural artisans for increasing their productivity and earning capacity.
11. To design tailor made/crash programme for our Centre Managers, entrepreneurs and industrialist to keep them abreast with the latest technology.
12. To provide assistance to the private sector in the creation and enhancement of institutional and technical infrastructure so that they can compete in the international market.

The Scope of the Technology Incubation Programme

According to FMST (2005), the scope of the technology incubation programme is to nurture the development and commercialization of:

1. Low technologies;
2. Manufacturing of simple equipment and machineries; Up grading of traditional technologies; Handcrafts, etc;
3. Medium technologies;
4. Manufacturing of electrical and electronic components and equipment; chemical processes and manufacture of plastics items; manufacturing of scientific equipment, etc.
5. High technologies;
6. Biotechnology Processes and Products; software and hardware; space technology; artificial intelligence; robotics
7. Emerging technologies
8. Advance materials; nano technologies; and others.

Technology Incubation Schemes

Pre-incubation

Pre-incubation are the activities of the entrepreneurs prior to admission into the incubation programme.

Incubation

Resident Incubation: In this scheme, entrepreneurs are tenants of a Technology Incubation Centre (TIC). At the TIC, affordable share facilities such as working spaces, central workshop, equipment and laboratories, offices, hand-on management assistance,

access to financing, networking and exposure to critical business support services are provided to enhance the success of the enterprise during the incubation period, which ranges from one (1) to three (3) years.

Non-Resident/Virtual Incubation: In this scheme incubation services such as access to resources (knowledge providers, finance, linkages/networking, etc) are extended to entrepreneurs outside the TIC.

Post Incubation

Some intervention measures such as monitoring services, linkages/networking to capital and knowledge providers (local and international), etc are extended to graduates of the programme to ensure their sustained competitive growth.

Roles of National Board for Technology Incubation

The role of NBTI according to FMST (2005) includes the following:

i. Policy guidelines for the execution of Technology Incubation Programme;
ii. Undertaking feasibility studies for the establishment of Technology Incubation Centres;
iii. Providing technology focus for TIP;
iv. Management of the entire programme;
v. Provision of specialized and customized infrastructure;
vi. Provision of a central facility workshop, equipment, laboratories for the technical development needs of the entrepreneur;
vii. Granting of development fund (seed capital), a non-interest revolving loan, to entrepreneurs in partnership with relevant stakeholders for sustenance of the programme;
viii. Facilitating linkages with knowledge-based and external service providers; and
ix. Provision of marketing outlets through exposure to local and international trade fairs and exhibitions in collaboration with Nigeria Export Promotion Council,

In addition to the role of NBTI enumerated above, the host state, entrepreneurs that are involved in the programmes, private sectors as well as tertiary institutions have roles to play. These roles are as highlighted by FMST (2005) and are also listed below:

Roles of the State Government

i. Provision of technology parks for the relocation of the entrepreneurs after graduation;
ii. Providetechnicallyfeasibleandcommerciallyviable R&D resultsandinventions;
iii. Providetechnicalsupporttothe TICs;
iv. EstablishsustainedInstitutionallinkageswiththeCentres;
v. Collaboratewith relevant tiersofGovernmentfortheestablishmentof TICs; and
vi. Establishinstitusion-basedIncubatorstocommercialize R&D results

Roles of Entrepreneurs at the Technology Incubation Centers

i. Provide Business Plan thattranslatescommerciallyviable R&D results, inventionsand/orindigenousknowledgeintogoodsandservices,
ii. Providetake-offcapitalforthebusiness,
iii. Providebasicmachineryforthetake-offoftheenterprise,
iv. Providerawmaterialsfortheenterprise,
v. Provideadequatemanagementforthebusiness,
vi. Provideperiodicreport; and
vii. Abide bytherulesandregulationsofthe TIP.

Benefits of Technology Incubation Programme

The benefits of Technology Incubation (when best practices are employed) to the different stakeholders include:

i. Entrepreneurs (Tenants)

It enhances the chances of success, raises credibility, helps improve skills, creates synergy among client-firms, and facilitates access to: mentors, information and seed capital.

ii. Governments

It would help overcome market failures, promotes regional development, generates jobs, incomes and taxes, and becomes a demonstration of the political commitment to small businesses.

iii. Research Institutes & Tertiary Institutions

It helps strengthen interactions and collaboration between the knowledge-base and the industries, promotes the commercialization of research results, and fosters enabling environment which encourages Faculties and students to maximize their potentials/capabilities

iv. Local Community

Enhances the creation of entrepreneurial culture, as well as local incomes with majority of graduating businesses settling within the area

Table 1: Some Specific Research Commercialised at Technology Incubation Centres in Nigeria

S/N	TICs	PRODUCT OF R&D	SOURCE OF R&D
1.	Lagos	1. Full Fat Soya	RMRDC
		2. Beni Seed Oil Extract	RMRDC, FIIRO
2.	Kano	1. Neem Oil for Neem Soap	NARICT
		2. Automatic Filling Machine	Private R&D
3.	Aba	1. Scourging Powder	Private R&D
		2. Mr. Flush Chemical	Private R&D
4.	Minna	1. Rice Husk in making ceramic glazing machine	PRODA Technology
		2. KununZaki preservation	FIIRO
		3. KununZaki processing machine	SEDI – Enugu
		4. Chalk moulding machine	
		5. Cassava bread and cake	SEDI – Minna
		6. Bread fortification with protein	FIIRO
		7. Poultry feed calcium enhancement	FUT – Minna
		8. Shea butter free fact acid purification technique	FUT – Minna FUT - Minna
5.	Nnewi	1. Amplifier	CAT - Awka
		2. VHF/UHF Boaster	CAT - Awka
		3. Stabilisers/Inverters	CAT - Awka
6.	Calabar	1. Bricks and Roofing Tiles	NBRRI
7	Enugu	1. Fire retardant solution	Private R&D

Source: Ndagi 2017

Conclusion

In accomplishing commercialization of R&D output, incubators use strategies such as increasing access to capital, the one stop shop approach, technical and business management training, contract procurement assistance, creating networking opportunities through clustering, export assistance and technology transfer assistance. These services are provided through collaboration with other economic development and entrepreneurship development organization within the same region. The national policy on science, technology and innovation (NSTI) should provide a strategic framework for government-university/research-industry/entrepreneurship-society/market linkage to effectively and efficiently facilitate commercialisation of R&D output for national development.

Technology incubators play an important role in transferring research output from universities to industry. They are statutorily to support and nurture the development of technology value-added small and medium-sized enterprises (SMEs) and strengthen the

country`s economic competitiveness for national development. Universities to commercialize their research outputs, technology incubators have been identified as key intermediaries to fill the gap between R&D and commercialization. As a result, many countries have supported these institutions as tools for commercialization and major contributors to knowledge-based economies. The most equipped commercialization team is one which is comprised of four characters, i.e., innovator or inventor, investor, technology expert, and entrepreneur (Shaverdi and Baghdadi, 2010). Inventor is a person who creates and presents a product or process which is either new or better to the existing ones and investor is an individual who invests in properties such as shares, products, and ideas with an aim of gaining profits. In addition, an entrepreneur is a possessor of an idea, an enterprise, or a high-risk investment company that voluntarily accepts the inherent risks associated with starting and growing a new business, product or service. Finally, technology expert is an individual who applies scientific knowledge to practical problems solving.

Recommendations

1. National Research Fund, Presidential Standing Committee on Inventions and Innovations, National Risk fund, National Innovation fund establishment and harmonization.
2. Establishing and Strengthening of IPTTO
   Universities require to establish fully fledged technology transfer units or consultancy bureaus, equipped to undertake patent searches, assess the novelty of innovations, pay the cost of processing patent applications and take care of the marketing of the invention and their commercialization, as well as the negotiation of the licenses and royalties.
3. Monitoring and Evaluation
   Universities should set targets on IP to be commercialized every given agreed period and commit budget for its implementation. In addition, there is need to develop an implementation strategy with guidelines for key performance indicators of all commercialization initiatives developed by universities to help monitor and measure their outcomes.
4. Capacity-Building in Relevant Skills and Policy Development
   Lack of entrepreneurial culture by staff (some faculty members have a purely academic orientation and don't have a lot of interest in dealing with private companies) need to be promoted. Support for training to students and early career researchers in commercialization to develop entrepreneurial skills and intellectual property management among academic staff and students is very key.
5. University Science Parks and Technology Incubators
   Supporting the establishment and management of university science parks and technology incubators for the purposes of technology transfer and management skills to run the facilities is strongly recommended
6. Research Commercialization in humanities
   Fields, like the humanities, may have limited possibilities for research commercialization. However, Innovation should also cover humanities areas such as governance, social, rural, urban, industrial corporate, education, health care, transportation, social safety nets and branding.

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