Job Creation through Commercialisation and Industrial Utilisation of Engineering Research and Development Results in Nigeria

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ABSTRACT

The limited development of Nigeria's industry is a consequence of low utilisation of capacity. This can be traced to the low industrial utilisation of engineering research and development (R&D) results. This poses serious concerns to the profitability of resources invested in research programmes. R&D is crucial to nation's technological and economic development. This paper examines the economic values of technological advancements in terms of innovation, invention, and diffusion. It highlights the need for commercialisation and industrial utilisation of R&D results in Nigeria. The nature of R&D is stressed. It also shed light on stages in commercialisation and industrial utilisation of R&D results. The report finally lay emphasis on the problems affecting commercialisation and industrial utilisation of R&D results and strategies that can help to successfully commercialise, industrial utilise R&D results to produce new or improved products and services in Nigeria are suggested.

Keywords: Job creation, Commercialisation, Industrial utilisation, Engineering R&D results, Nigeria.

1.0 INTRODUCTION

R&D means investigation into products; in business, agriculture, industry and other areas of human endeavour. It involve works of investigating improved processes, products, and services of developing new ones (Momah, 2003). Research may be defined as systematic gathering of data and information and its analysis for advancement of knowledge in any subject. Research attempts to find answer to intellectual and practical questions through application of systematic methods. Research seeks to make basic discoveries and uncover new principles or facts so far unknown or unrecognised. R&D includes activities of these three kinds (Momah, 2003). First there is basic research which is original investigation for the advancement of scientific knowledge which does not have immediate commercial objectives e.g. an engineer who develops operation research model without any particular application in mind is performing basic research. Applied research is research that is aimed at a specific practical pay off e.g. a project designed to determine the properties of a new polymer that a chemical firm plans to introduce would be applied research. Development tries to reduce/translate research findings to practice. Major development projects attempt to bring into being new products and processes.

Undoubtedly, it is the effective conversion of R&D results into useful goods and services that actually determines the impact of the R&D on the nation's economy. Of all the problems and lapses on our march towards industrial developments, the most disturbing is the non-commercialisation of R&D results obtained from R&D institutes and universities where lots of investment had been made. R&D results are not being efficiently converted into valuable goods and services. There appears to be no evidence to show the extent of transfer of technology from R&D institutions. Despite the fact that there are over fifty (50) resource based research institutions in the country, the outcomes from research activities of these institutions have not been developed to the benefit of the national economy because the development aspect of R&D has not received the right attention in the national development plan (Ogunwusi & Ibrahim, 2014). Also, it is a known fact that the nation has generated volumes of

research results some of which have led to patentable inventions (Ofi, 2008). Regrettably however, most of these publications simply ended upon the shelf once they have been utilised for much cherished promotion exercises of the individual researcher(s). Very little attention has been paid to commercialisation and industrial utilisation of these research results and invention. The application of scientific knowledge gained from academic research can present solutions to some of the problems facing a nation. Research commercialisation transforms technology birthed from research activities into useful marketable products or services. However, Nigerian universities and other research institutes still do not make significant contributions to the socio-economic development of the nation despite the high number of students that engage in research projects. Little wonder why there is a dearth of local solutions and over-reliance on imported products in the country. Thus this study intends to investigate how the R&D results can be effectively utilised and commercialised to produce new or improved goods and services, especially those that directly utilise locally available manpower and raw materials for the purpose of satisfying local needs and export. The potential of fully exploring commercialisation and industrial utilisation of R&D results are considered. The rest of this paper is structured in five parts. Section II examines the economic values of technological advancements in terms of innovation, invention and diffusion. Section III provides much more highlight on the need for commercialisation and industrial utilisation of R&D results in Nigeria. The nature of research results and development is stressed in Section IV. Section V elucidates commercialisation and industrial utilisation of R&D results while section VI deals with the problems militating against the commercialisation and industrial utilisation of R&D results into products and services. The recommendations and measures for successful commercialisation and industrial utilisation of R&D results are suggested in section VII. Section VIII presents conclusion.

2.0 TECHNOLOGICAL ADVANCEMENT: INVENTION, INNOVATION AND DIFFUSION

R&D constitutes the life wire of all scientific and technological advancement. Technological advancement shifts the economy production possibilities enabling the economy to obtain more goods and services when utilised. Therefore, technological

advancement in this light can be viewed as a three step process (Sinyanbola, et al., 2012 ; Momah, 2003):

i. **Invention:** The most basic element of technological advancement is invention. This is the first discovery of a product or process through the use of imagination, ingenious thinking, and experimentation and the first proof that it will work. While invention is a process, the result is also called invention- which is a form of the first prototype (basic working model). Invention is strictly based on scientific knowledge. Government encourages invention by providing originator with a patent, an exclusive right to sell any new and useful process or product or machine for a set period of 20 years from the time of application.

ii. **Innovation:** This is the second element of technological change draws directly on invention. Innovation is the first successful commercial introduction of new technology. The first part of this process takes place in the interval between the establishment of technical feasibility and the beginning of commercial development of the raw product or process. The second part of this process takes place in the time interval between the beginning of application of the new process or product. This time interval consist of a number of distinct stages applied research, preparation of product specification, prototype or pilot plant construction, tooling and construction of manufacturing facilities, and manufacturing and marketing start up. In this entire time interval averaged about five years for instance post war innovation. Innovation is of two broad types: product innovation, which involves new and improved product and services; and process innovation, which involves new and improved production or distribution methods (Momah, 2003). Unlike invention, innovations, as such, cannot be patented.

iii. **Diffusion:** This is the spread of an innovation through imitation or copying. To take advantage of new profitable opportunities or slow the erosion of their profit, new and existing firms emulate the successful innovation of others. This is possible because innovations are not strictly backed by intellectual property law, e.g. patent, copyright, trade mark, trade dress, licencing, franchise etc.

3.0 THE NEED FOR COMMERCIALISATION AND INDUSTRIAL UTILISATION OF ENGINEERING R&D RESULTS IN NIGERIA

The manufacturing sector in Nigeria is small. The contribution to the Gross Domestic Product (GDP) is less than half what it should be compared to some advanced economies (Momah, 2003). There is a need to gradually develop this sector in order to place Nigeria in the league of advanced nations. Industrial processes depend on input, human resources and equipment. The production line of an industry that relies on obsolete equipment would be cumbersome and the products expensive because of low production level and high consumption of resources. The aftermath is that the product unit price is always higher than the imported alternatives.

In Nigerian market today, it is common to see foreign products that are cheaper than the locally made goods which are often being preferred by the consumers. The inability of the industry to compete with their foreign competitors has led to closure of many industries thereby throwing their workers to the labour market while the industries resort to alternative buying and selling to remain in business. But when the production line of an industry is driven by modern/appropriate technology arising from findings of technological R&D, there will be high efficiency, low consumption of resources, with high output per unit time. This results in low unit cost, affordable products, high product demand, improved standard of living and overall growth in the economy of the country.

Moreover, the dependence of Nigeria's manufacturing sector on foreign input (raw material, personnel, machinery and equipment) is much. Devastating effects of this are made manifest in the winding up of many industries in the manufacturing sector. The problems militating against optimum capacity utilisation of manufacturing companies can be solved by evaluating investment of the manufacturing industry in the light of appropriateness and sustainability of technologies. Most R&D results evolve from/around traditional and cultural milieu of a people. It is more akin to appropriate technology which connotes a given level of contemporary technology in relation to the level of development of the environment under consideration. This implies that with the successful commercialisation and industrial utilisation of R&D results, more locally available raw materials, spare parts and labour will be required, reduction in cost of production due to optimal allocation and use of available resources, less man-hours, cheaper and high quality manufactured goods, reduction in labour turnover due to the need to engage more hands for productive efforts, fall in

unemployment, rise in GDP and standard of living of populace (Nwachuckwu, 2000; Lawal, 2017).

Furthermore, there is a need for Nigeria to promote deliberately the establishment and growth of small and medium-scale companies which have good knowledge of modern production technologies and which are willing to develop new ideas into marketable products or services. They serve as the soil holding the roots of the big companies and from which such company draw services, materials and goods to nourish their growth while the inventor-entrepreneur will continue to play an important role in industry, the growth of corporate professional research and development must be seen as an important aspect of industrial growth.

4.0 NATURE OF ENGINEERING R&D RESULTS IN NIGERIA

Research is generally aimed at optimisation of production function vis-à-vis constraint-improved product and process. Thus its results are empirically proven after services of experimentation and testing. This is basically a set of detailed specification and/or prototype. The objective of a research may include (Sinyanbola, et al., 2012; Momah, 2003; Nwachuckwu, 2000; Ogunwusi & Ibrahim, 2014): cost reduction of a process or product; improved quality of a product; improved material handling; faster and efficient process; reduced labour requirement; improved safety: (personnel, equipment, and environment); search for cheaper and/or available raw material alternative; improved energy conservation; improved machinery, equipment and plant (in terms of spare part availability), turn waste to wealth and reduced environmental pollution (noises, air etc.).

One of the major problems limiting contribution of innovation to industrial development in Nigeria is the low level of fund available for innovation activities. While government is the sole sponsor of R&D activities in Nigeria, the funding level is abysmally low at about 0.11% of the GDP (Ogunwusi & Ibrahim, 2014). In addition, there is lack of trust by the private sector on innovation from public research institutes and the universities as a result of inadequate infrastructural facilities. Also little or no interaction exists among major actors in the innovation system leading to high level of duplication. The facilities in the public research institutes and Universities in Nigeria have degenerated so much that most are operating at the

lowest ebb of infrastructural availability. In the 70's most public research Institutes and Universities were at par with those in the United Kingdom and the United States of America Vis a Vis quality and quantity of state of art equipment and facilities. As from the mid part of 1990's to the present, the Nigeria economy had been bastardised and development nosedived as a result of policies that encouraged the devaluation of the naira and acute corruption in the polity.

Today, most public research institutes and universities in Nigeria are parading obsolete equipment where available. This is retrogressive and negates the principles of sustainable development. It also led to questioning the quality of innovations obtainable at such institutes. This perhaps may have been part of the issues the public university lecturers in Nigeria are agitating for improvement of facilities and conditions of service which has led to five months industrial action by the lecturers in Nigeria. According to Okebukola, (2002), by 1996, the quantity and quality of research in public universities had declined to an all-time low. This has led to low level of local patents in the Country. For instance, only 74 local patents (as against 122 foreign patents) were registered in Nigeria between 2000 and 2006 while the figures are in range of tens of thousands for China and India (Siyanbola, 2008). According to Akinsola (2007), the Obafemi Awolowo University obtained 47 grants for projects between 1998 and 2002, and 87 between 2003 and 2007, most of the projects were either surveys, impact analysis, appraisals, evaluation or analytical studies that may not impact directly on industrial development. Thus, as a matter of urgency, there is need for upgrading facilities in public research institutes and Universities in the Country. As has been reported by various authorities, Nigeria is blessed with multifarious raw materials. These include agricultural and mineral raw materials.

Presently in Nigeria, efforts are being made by different public research institutes and tertiary institutions to develop these raw materials simultaneously. This has led to duplications, waste of scarce resources and manpower. Fortunately the Nigerian manufacturing industry is made up of ten sectors, each with easily identifiable raw material problems. In the wood and wood products and the pulp and paper sectors of the economy, the major problems are dwindling availability of economic wood

resources and absence of local source of long fibre raw materials respectively. These have led to closure of industries and disengagement of the workforce in a number of industries. These calls for a strategic plan that will deliberately outline and analyse the raw material problems within the sectors and build scientific capacity and competences in the areas identified for sustainable development and production of raw materials for such industries locally. Building competitive advantages in these fields will reduce foreign exchange expenditure and enable the country to supply the vast market available in West Africa or to catch up with countries with such advantages. Also this will assist in the identification of raw materials on which exhaustive national R&D will be concentrated in order to identify all useful products and components of industrial relevance as was done for sugar in Brazil and Oil palm in Malaysia. Today, the public research institutes and universities depend solely on government funding of research and development activities. As government resources are dwindling due to absolute dependence on oil export, the amount of money available for funding public R&D also have to reduce. This is a major bane of industrialisation in Nigeria.

4.0 COMMERCIALISATION AND INDUSTRIAL UTILISATION OF ENGINEERING R&D RESULTS IN NIGERIA

Commercialisation is the process of introducing a new product or production method into commerce making it available in the market. It also includes moving from the laboratory into even limited commerce. Many technologies begin in a research and development laboratory or inventor's workshop and are not practical for commercial use in their infancy (as prototypes). The developed segment of the research and development spectrum requires time and money as systems are engineered that will make the product or method a paying commercial proposition (Ofi, 2008). Ofi (2008) mentioned that beyond commercialisation (in which technologies enter the business world) can lay consumerisation (in which they become consumer goods, as when computers went from the laboratory to the enterprise and then to the home, pocket or body). Although the Structural Adjustment Programme (SAP) of the eighties failed within most of it objectives (Momah, 2003), there are records of achievements of commercialised R&D results. This includes (Momah, 2003): mechanised production

of garri; pasteurisation of palm wine; development of malt from sorghum which has saved Nigerian Trillion of naira; development of hybrid maize which yields up to five times the normal maize; development of drugs of medicinal plants for the management of malaria, sickle cell anaemia, hypertension, ulcer, diabetes; refining of kaolin and its use for ceramic ware; technologies for producing hundreds of seed yams from one tuber of yam and similar number of cassava cuttings from single stick of cassava; development of high yielding oil-palm hybrid seedlings; development of cheap building material; and design and construction of Demore Rover- a Nigerian made prototype car by Late Professor G. Ezekwe and others at Projects Development Institute, Enugu (PRODA). One of the examples of the waste to wealth creation through commercialisation and industrial utilisation of R&D results (from the laboratory to the market), carried out by University of Ibadan researchers, is the development of Organo-Mineral Fertilizer Plant at Bodija market, Ibadan which converts the biodegradable components of market wastes into fertilizer (Suleiman, 2015). 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 (Siyanbola et al; 2012). Translating these outcomes into successful products would mean new jobs creation and economic empowerment for the people. But then, how to achieve this feat has rather been difficult. Less than 2% of the R&D in Nigeria have been commercialised in view of this. Sinyanbola et al (2012) acknowledges the role of networking and collaboration among key stakeholders in the commercialisation process.

An innovation is said to be accomplished when an invention or the findings of a research activity has been developed into a marketable new product. Innovation is the ultimate aim of any invention, applied research or experimental investigation. Thus, there is a need to have a good crop of innovative firms to translate even the little inventions in the country to commercially marketable products.

5.1 Stages in Commercialisation and Industrial Utilisation of Engineering R&D results in Nigeria

The process of commercialisation of R&D results and product development is time consuming and it is a lifelong process. The journey from idea to the shelf in the supermarket is a very long and sometimes frustrating one. Whilst it is estimated that it takes about seven years to execute R&D project to commercialisation stage (the Americans in recent years have been trying to reduce the period to three years) the actual commercialisation may be a lifelong process (Ofi, 2008). Once the viability of the commercialisation of R&D results has been identified, a critical assessment of the viability and marketability of the product as well as the accompanying cost benefits is undertaken through appropriate feasibility study. Moreover, the four steps to be undertaken in a detailed feasibility study in order to commercialise technological R&D results (translating patents and ideas to produce goods or services) for industries are (Lawal & Lawal, 2004):

Step 1: Idea generation: There should be a clear concept or idea of the products/services upon which the business will be built. Examples of items for small-scale enterprises that an engineer-entrepreneur could be involved in are software development, design and fabrication of machines/parts, computer training, converting the biodegradable components of market wastes into fertilizer (wastes to wealth), etc.

Step 2: Project Ideas evaluation: Evaluation of project idea can be done at primary (pre-feasibility) level and at final (feasibility level). A primary assessment will determine if the entrepreneur can meet the project's requirement of: (i) the level of investment required; (ii) the type of technical or engineering skill involved and (iii) the market demand for the product or services. If only the answer to the primary evaluation are satisfactory can feasibility studies should be done. The techniques of feasibility studies are well known and well covered in such works as Lawal, et al., (2005); and OECD manual (2012), which lay emphasis on project analysis in developing countries.

Step 3: Detailed project design: This involves a detailed specification of all facilities necessary to satisfy performance and functional requirements of the proposed project. It includes total specification of plants and machinery, building and infrastructure, management and information systems, marketing or promotional systems, production/operational systems and financial policies.

Step 4: Project implementation: This involves the use of critical path method in preparing and scheduling the following major activities for small-scale enterprises: Capital loan formation; Enterprise formation as a legal entity preferably as a limited liability company; Development of land, building and infrastructural facilities; Procurement and installation of plants, machinery and equipment; Procurement of raw materials, requirement and training of personnel; Requirement and training of personnel; and Commissioning the factory by bringing the new facilities, organisation and systems up to the target standards of initial output and operational efficiency as quickly as possible.

5.2 Interrelated Roles Played By Management in the Successful Application of Appropriate Technology in commercialisation and industrial utilisation of R&D results in Nigeria.

Furthermore, the following interrelated roles must be played by management in the successful application of appropriate technology in commercialisation and industrial utilisation of R&D results to produce new or improved products and services (Lawal & Lawal 2004):

(i) Personnel selection: The best staff selection methods to be adopted include invitation for application for employment, conducting interviews for those invited, and final selection based on merit;

(ii) Staff motivation: The methods of motivating workers effectively include enrichment of job rotation, proper apportioning of jobs to the specifications, remunerations, which include prizes, awards, scholarships and gifts as well as creating a good working environment.

(iii) Adopting effective costing methods: Small scale companies will survive if the engineer-entrepreneurs adopt good costing method. Machine hour rate can be adopted for the small scale companies. Machine hour rate account for the intrinsic characteristics of the job by allowing for judgemental decision making, aggregate costing as well as timely and inexpensive cost prediction based on current status and past performance records. Machine hour rate is the total cost of using a machine in an hour. Machine hour rate is based upon a study of the actual overhead expenses of the

machines used. Factors such as capital investment, depreciation, insurance, repair and maintenance, floor space, power and lighting costs are calculated. All these factors are added together and then divided by machine hours to give machine rate per hour. Product made on the machine are then charged at this hourly rate based on machining time involved.

(iv) Value engineering utilisation: companies that have to design products for manufacture have to apply the necessary value engineering techniques on the design products. This is the application of the concept of value analysis at the design or pre-mature stage of the component part with a view to cut down the unnecessary cost without affecting or impairing the function and utilities of the product. It entails having a consortium of experts in the various aspects of the business who have to criticize the design and offer helpful modification that would result in and improved product design;

(v) Value analysis: This involves examining the design, function and cost of each component in order to produce it economically without decreasing its utility, function or reliability. It is normally applied to existing rather than a new product.

(vi) Sales forecast: Forecasts are necessary in sales analysis, market planning, production planning, budgeting, logistics planning, product planning, inventory control, material requirement planning, purchasing and strategic planning engineer entrepreneur should apply market survey and group opinion to determine the demand of newly introduced products and later applied other techniques when there are production data;

(vii) Marketing: Marketing functions including market research, sales forecasting, advertising, sales promotion, selling, packaging, servicing and handling of inquires and orders from the customers. A carefully selected group of variables in marketing is required to be able to perform the aforementioned activities effectively and efficiently. It is possible to adapt speedily and profitably to changes in the marketing environment by using the marketing mix (product, price, place and promotion) as a tactical tool of the firm's marketing plan. The enterprises must integrate all the components of the marketing programme into coordinated market mix and back up with technical assistance such as computers for accounting purpose, sound system for communication and vehicles for movement of goods and sales personnel into coordinated market mix;

(viii) Equipment maintenance: The failure of many industries in Nigeria is due to poor maintenance of equipment. Manufacturing companies should ensure that production machine is adequately maintained by having an effective maintenance unit attached to the enterprises. In the case where maintenance unit is available/adequate preventive maintenance such as lubrication, inspection, adjustment etc. may be necessary to prevent future breakdown of machine.

Over the years the input from the research institutions has been at low ebb because of some problems while the industry on the other hand is faced with some challenges. It is often being said that the small number of "invention" and locally designed machines which are capable of being developed into marketable products are not being exploited commercially. It has also been claimed in many conferences that our industrialists are not interested in developing such inventions and products. These problems deserve further attention especially now that the country is relying on the industrialists to look inwards for their activities.

5.3 Case Study of Waste to Wealth Creation through Commercialisation and Industrial Utilisation of R&D Results: The Organo-Mineral Fertiliser Plant Development Project (From the Laboratory to the Market)

The Organo-Mineral Fertiliser Plant Development Project (from the laboratory to the market) carried out by University of Ibadan researchers, is a typical example of the waste to wealth creation through commercialisation and industrial utilisation of R&D results that led to the development of organo-mineral fertiliser plant at Bodija market, Ibadan which converts the biodegradable components of market wastes into fertiliser as stated in Suleiman (2015).

A professor and his research team from the Department of Public Health, University of Ibadan were concerned with the provision of solution to the environmental problem created by market wastes spread over our cities. Riding on the slogan of "wastes to wealth", they stumbled on the idea of converting the biodegradable components of market wastes into fertiliser. Convinced of its feasibility, the Professor of Public Health approached the Department of Agronomy, University of Ibadan for research support. This culminated in a group of researchers (2 Professors assisted by 3 graduate students) developing an organo-mineral based fertiliser utilising mainly the municipal wastes identified by the Public Health Department. The organo-mineral

fertiliser is a challenge to the synthetic fertiliser, as the world is moving towards organically-grown food crops. The field-testing of the developed organic fertiliser in some parts of the country proved highly successful. All that was involved at the research stage was the University Of Ibadan Senate Research Grant Of ₦50, 000. The project later attracted the attention of the Raw Material Research and Development Council (RMRDC), which provided about ₦ l.0 million for the development of the prototype system to produce the fertiliser. To move from the laboratory stage to the development phase, the researchers had to invite engineers to help design appropriate system to implement the laboratory stage process. It was at this stage that the professor of mechanical engineering was invited to participate in the project who also invited a postgraduate student to take it as his Ph.D. project. Fortunately the project was finally approved.

The engineers came up with the process design in collaboration with the agronomists on the project. Since the fund made available was inadequate to construct the entire plant, the machines involved were prioritized. The pelletizer was the most crucial component of the plant. The engineers came up with the design and production of working drawings of this machine in collaboration with a metal worker outside the University who later fabricated the machine using materials and components from all sources. The machine worked quite well and provided them with basic data for the final design of the entire system, including sorters, millers, mixers, and baggers. At this stage, 3 engineers, a metalworking outfit with 2 technicians, 2 craftsmen and 10 artisans were involved. This brings the number of people involved to 22 from the original 5 agronomists. The project attracted the Oyo State Government, which provided funds for the fabrication and testing of the final design. The fabricated plant was located at the Bodija Market, a big market generating considerable wastes. At the operational stage it started producing close to 100No. 50 kg bags per day of powdered fertilizer with operations mainly hampered by the epileptic power supply. The fertiliser was well accepted by the farmers. The postgraduate students from the Department of Agronomy shouldered the responsibility for testing the soils in different locations in the country and coming up with the required composition of the fertiliser. The stipulated composition formed the basis of production by the mechanical engineering postgraduate researcher. Suffice it to note that the project was a big success with several Ph.Ds awarded in agronomy and mechanical engineering.

Surely the mechanical engineering student's Ph.D thesis combined the traditional material properties and machine design to achieve well-defined products within the norms and practices of the discipline. The same can be said of the Ph.D thesis of the agronomy students, which must have been based on the norms, and practices of agronomy as a discipline. This is a classic case of an 'additive' type of multidisciplinary research (See Lawal, et al., (2005) for detailed feasibility study of development of small scale industry in Nigeria).

5.0 PROBLEMS MILITATING AGAINST THE COMMERCIALISATION AND INDUSTRIAL UTILISATION OF R&D RESULTS IN NIGERIA

The following are the problems militating against the commercialisation and industrial utilisation of R&D results to produce new or improved products and services in Nigeria (Momah, 2003 (Ogunwusi & Ibrahim, 2014; Nwachuckwu, 2000; Sinyanbola, et al., 2012) :

- Lack of enabling environment thereby leading to professional limitations of researchers; The poor working conditions of inventors, innovators, and researchers including remuneration, training, recognition etc.; Poor coordination of research and development effort; Poor patent culture thereby leading to lack of patent marketing; Lack of necessary facilities to conduct R&D; Poor attitude of Nigerians to research and development; Poor and inadequate library facilities and information services; Poor management of Intellectual Property rights;
- Weak Intellectual Property Rights (IPR) laws and enforcement; Inadequate research funding; Lack of awareness on existing R&D outcomes; Inadequate personnel capability in industry; Uncompetitive cost of production in industry; High cost of capacity in industry; Low aggregate demand/customer purchasing power;
- Lack of National coordination of R&D activities/results thereby leading to duplication/dissipation of effort; Lack of linkages between industry, university and research institute; Lack of critical mass of personnel and facilities thereby leading to weak institutional provisions; Poor technological base prevalent in the country; Low level of entrepreneurship; Poor technology management; Poor targeting of research and market orientation that have resulted in irrelevance of R&D results/inventions;

Poor quality assurance of local R&D results thereby marking it unattractive to domestic industry;

- Apathy of financial institutions towards commercialisation of R&D results; Lack of confidence by venture capitalists thereby leading to level of absence of a well-recognised financially strong and viable agency to promote and drive commercialisation process; Lack of a national policy that protects local products of R&D results and provide a strong marketing strategy; Low level of motivation of researchers; Professional limitation of the researchers;
- Lack of basic infrastructural facilities such as electricity, access road and portable water supply at the preferred location for citing the industry; Tedious marketing effort for poor quality products of local R&D results; Prevailing brain-drain. Best brained are lured outside Nigeria; Need to restructure and re-equip our educational system. Science and technology area based on sound/functional educational system.
- Obstacles to cooperation of manufacturing industry with research institution/universities towards utilising R&D results which include (Nwachukwu, 2000; Bamiro, 2004; Suleiman, 2015): Lack of practicality; Lack of realism and hostility to compromise, prompted by the search for scientific facts; Lack of regard for deadlines and profitability; Communication difficulties, confidentiality problems; and Attitude of many inventors, especially unwillingness to cooperate with industry, scientists and businessmen having different value system.

7.0 RECOMMENDED STRATEGIES

The following suggested strategies and measures can be implemented to enhance the effective commercialisation and industrial utilisation of R&D results to produce new and improved products and services in Nigeria:

1. Government should:

- Identify R&D results that can be commercialised and foster such commercialisation for maximum impact within a minimum time frame, resource etc.; identify obstacles to effective commercialisation of obtainable research and development results and tender legally backed solution;

- adopt economic policies that favour local producer (Nigerian made goods) rather than imported foreign finished goods; enact a strong policy to make foreign companies undertake considerable amount of their R&D activities in the country;
- through Raw Materials Research and Development Council (RMRDC) develop raw materials such as iron and steel, non-ferrous metals, plastics and ceramics;
- reorganise Ministry of Science and Technology to police all the R&D projects going on in the country with a view to encouraging private investors in converting established R&D work into industries;
- through CBN to keep inflation and interest rate at single digit; provide an enabling environment for manufacturing companies; improve electricity situation in the country; make adequate provision for a pool of funds to be completed for and accessed by researchers for the commercialisation of viable research and development results;
- through Ministry of Education overhaul engineering curriculum to reflect the real needs of Nigerian society which will ensure the development of basic skills and training of graduates for self-employment; and invest in science, technology and innovation programmes to diversify the economy.
- construct basic industries such as iron and steel plants, machine tools industries, heavy electrical, petrochemical, gas and bitumen industries; enhance improved relationship and linkage between Research centers/ institutions and industries for better application/utilisation of research and development results;
- through National Office for Technology Acquisition and Promotion (NOTAP) collate information on new inventions and scientific breakthrough by inventors, scientists, researchers and research institutions as well as link the engineer-entrepreneurs/private investors with research and development results such as agricultural and food process machines etc.; and
- reorganise Ministry of Science and Technology to police all R&D projects going on in the country with a view to encourage private investors in converting established R&D work to companies; encourage and support research and development of indigenous goods up to commercialisations.

2. NSE and COREN should:

- support genuine research and development for local materials and local condition to solve professional problem confronting the nation and put in place a system which shall facilitate the commercialisation (and patent) of applicable research findings;
- liaise with financial institutions to provide adequate support to products and services resulting from the research findings; recognise that turning ideas into products, establishment and management of small-scale engineering concern is a technological function that is extremely critical for the recovery and sustained survival of Nigeria;
- encourage more graduate/professional engineers to utilise R&D results and to become small-scale industry entrepreneur;
- through Divisional activities organise technical session to help giving necessary advice to prospective engineer-entrepreneurs to utilise R&D results (turn ideas into products or services) and to develop and manage their own business;
- sensitise Government on the urgent need to create the enabling environment for engineering to provide the means, methods and facilities for transforming the nation from its present state of backwardness to self-reliant industrial economy.

3. Technological R&D Institutions /Universities should:

- engage in research and development activities that can immediately be profitably exploited by industry; encourage group final year/post graduate project cutting across discipline and direct students' project to solve industry's problems; not hoard R&D results from colleagues;
- be creative, innovate, inventive and highly resourceful; investigate problems from industries with a view to finding possible solutions;
- meet industrialists, professional investors and philanthropists in the areas of further development and procurement of fund to actualise the desired objective;
- organise conferences and exhibition on New Products and Technologies for Small And Medium Enterprises as well as develop industrial villages within institutions as avenue for transmitting research and development into viable energy products and services and avenues to provide skills and experience to both students and lecturers alike;

- engage in aggressive marketing for commercialisation of their research outputs in collaboration with industries and organisations in their catchment areas in order to make researches more useful for economic development;

4. **Manufacturing companies should:**

- participate in R&D locally; establish R&D departments/units and carry out research in the use of local materials; play more effective role in the utilisation and commercialisation of R&D results; out-source to a contract research organisations, universities or state agency;
- be involved in the review of engineering curricula and development of research goals in research institutions for their relevance to the industry needs; cooperate with each other to promote innovation;
- meet a challenge for a critical need and link up with academia; design and produce locally made product as if it were meant for an international market; survey the market and identify competitors and then aim at a superior product having painstakingly gone through series of quality test.

5. **Inventor-engineer should:** serve as consultant in the process of commercialisation of R&D results and product development; try as much as possible to market knowledge and products in order to continue to break new frontiers and avoid losing focus;
6. **Engineer entrepreneur should:** equip themselves with leadership, investment, accounting and sales skills in order to have what it takes to translate engineering R&D results to produce products or services and to run engineering business both in attitude and ethics;
7. **Nigerians should**: patronise made-in-Nigeria goods as this will swing our engineer-entrepreneurs / private entrepreneurs from buying and selling syndrome to local production. This will further enhance the commercialisation of research results and help stem the spiral unemployment and social ills.

8.0 CONCLUSION

Effective commercialisation and industrial utilisation of engineering R&D results will open up new employment opportunities for teaming population, create wealth, reduce poverty, promote national development and sustain industrialisation as well as increase the participation of engineers in the technological and socio-economic development of the nation. The economic values of technological advancements in

terms of innovation, invention and diffusion has been examined. The needs for commercialisation and industrial utilisation of engineering R&D results in Nigeria have been highlighted. The nature of engineering R&D results is stressed and stages in commercialisation and industrial utilisation of R&D results are elucidated. The paper also emphasised the problems affecting the commercialisation and industrial utilisation of engineering R&D results in the country. Recommendations and measures for successful commercialisation and industrial utilisation of engineering R&D results were suggested.

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