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Public Research Institutes in the Nigerian (Bio)pharmaceutical System of Innovation

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LEARNING THROUGH INTER-ORGANIZATIONAL INTERACTIONS:

PUBLIC RESEARCH INSTITUTES IN THE NIGERIAN (BIO)PHARMACEUTICAL SYSTEM OF INNOVATION

Banji Oyelaran-Oyeyinka and Padmashree Gehl Sampath[1]

Abstract

Using field level data collected in Nigeria in 2003-2004, this paper examines the possibilities for learning through inter-organizational interactions in the country's biotechnological system of innovation, using public research institutes as an example. The paper considers inter-organizational interactions to be all forms of formal and informal linkages and contacts between various agents in the system of innovation, including firms, universities, traditional medicine practitioners, hospitals and other external agencies. Using results obtained in the survey and the experiences of other countries that have succeeded in developing biotechnological capacity, critical interactions and scope for policy interventions are discussed.

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1. INTRODUCTION

The experiences of several developed countries in building biotechnology-related competencies have focused attention on two important questions. First is the role of inter-organizational interactions in fostering learning through a broadened access to knowledge generation and transmission activities. Interactive learning, which can take three broad forms – competititon, network formation or R&D partnership – is central to the innovation systems framework (Edquist, 2004). Biotechnology relies on the presence of a complex science base that includes such disciplines as genetics, biochemistry, pharmacology, pharmacognosy, cellular biology and medical sciences (Meyer-Krahmer and Schmoch, 1998). As a result, innovation in biotechnology is conditioned largely by inter-organizational interactions. Most of these interactions are based on improving access to knowledge through both formal and informal channels, and therefore the relational dynamics among the key actors is critical in shaping the capacity of the system.

Second, biotechnology is an example of a new technology that can be integrated into *existing traditional strengths* in existing sectors, such as the drug sector. In the drug sector, biotechnological techniques contribute immensely to R&D through broadening the understanding of molecular triggers for good health and disease causation, thereby enhancing possibilities of drug development. However, while biotechnology has changed some aspects of drug discovery and development, the core technologies, such as those required for pre-clinical and clinical testing, marketing, and manufacturing, remain the same as for traditional drug research (Walsh, 2003; Chiesa and Toletti, 2004; Madhok and Osegowitsch, 2000). This enables one to focus on the capacity of existing institutions and organizational structures in countries to absorb new technologies in a dynamic perspective.

The importance of interactions in the biotech sector is widely acknowledged in the literature, especially relating to the medical and agricultural sectors, but has been discussed in various ways by different scholars, depending on their theoretical orientations. Specifically, the shift to inter-organizational collaborations in biotechnology has been explained in terms of a pervasive concern for access to knowledge, both tacit and codified, biotechnology being portrayed as a field in which innovations are incremental in nature (see for example, Foray, 1995; Scotchmer, 1999). In institutional economics, institutions are viewed as a means of economizing on transaction costs, and the significance of alternative modes of organization of economic activity lies in their relative advantages/disadvantages in helping parties deal with the various transaction costs. Accordingly, repeated transactions can be explained as strategic choices by

actors to deal with transaction costs imposed by behavioral factors of bounded rationality and opportunism and transactional factors such as uncertainty and asset specificity (resulting in lock-in effects) that forces them to choose specific governance structures over others (see Williamson, 1975, 1991, 2000). Whereas this explains firm/actor behavior, the role of learning through inter-organizational interactions is not fully dealt with in this approach (see for example, Lerner and Merges, 1998). Similarly, inter-organizational collaboration has been explained in terms of learning opportunities that arise from the centrality of networks (Powell *et al*., 1996).

Evolutionary technological change theory places learning as a central activity for building technology capabilities (Nelson and Winter, 1982). Their model focuses on micro-level "behaviour" represented by organizational routines and search behaviour within a selection environment. The organizational routine of a firm is likened to the gene in biological evolution (although they are not similar). Routines in turn are equated to habits that involve individuals in the firm with their skills and experiences.[2] In short, while routines apply to an organization, skill is an attribute of the individual.

The key concepts that explain the dynamic and transformational processes of learning over time are: diversity (variety and variation), selection, replication (innovation), inheritance, path-dependence and bounded rationality. These concepts are employed to explain the persistent change in economic systems that are in constant flux. An important assumption in innovation studies is that firms do not innovate in isolation, but rather do so in concert with, and within a network of, agents as well as in the context of institutional environments that support or hinder such efforts. Variety generation in evolutionary technical change explains the behaviour of these actors and relates to the existence of a population of agents (firms, organizations and individuals), products, processes and technologies. For instance, organizational variety creation is observed in the emergence of new biotechnology research units within universities and public research institutes in response to the biotechnology revolution (Henderson, Orsenigo and Pisano, 1999). New types of firms emerge as the competitive environment changes and as old economic regimes are modified or disappear. The new actors rely on new sets of knowledge bases, competencies and specialization that have to be mastered by learning. In this context, learning responses are not only technical, but also involve institutional and organizational innovation. This constant change explains the central importance of innovation to persistent changes in the economy and is responsible for persistent national, sectoral and firm-level differences in capabilities. For its part, selection reduces variety in organizations, firms, products, processes and technologies. Selection mechanisms have market and non-market

[2] Nelson and Winter (1982: 72) define a skill as: "Capability for a smooth sequence of coordinated behaviour that is ordinarily effective relative to its objectives". Skills contain elements of tacitness that are neither easy to communicate nor written down.

components that vary in intensity depending on the environment in which they are embedded (Metcalfe, 1998).

This paper seeks to analyse the importance of inter-organizational interactions in biotechnology-based drug research, using field-level data form Nigeria to draw attention to both the relevance of inter-organizational interactions for learning and the importance of flexible and non-rigid organizational structures. The paper employs the systems of innovation framework, in which innovation is an interactive process between a network of economic actors conditioned by policies and institutions acting at the national or sectoral levels; these policies and institutions condition the nature and extent of the actors' innovative behavior and performance. Within this framework, the main variables that condition interaction are: (a) absorption capacities of the various institutions (in terms of physical and human capabilities that make interaction possible in the first place); (b) the incentive structures for interaction (which account for the intensity of interaction); and, (c) policies and institutions at the macro level (which shape finance and investment possibilities, research system orientations, and competition) and micro levels (which shape incentives, technological capacities, and patterns of interaction) (see Cohen and Levinthal, 1990, Edquist, 1997, Meyer-Krahmer and Schmoch, 1998). Interactions thus includes all forms of formal and informal linkages and contacts between various agents in the system of innovation, such as firms, universities, and public research institutes, that determine what each one of these actors learn. Policies and routine interactions shape habits and practices over time that influence innovation patterns (Freeman, 1988).

The data used in this paper was collected in 2003-2004 as part of a study of the Nigerian biotechnology system of innovation. That study aimed at understanding the impact of biotechnology on the activities of firms, universities and public research institutes (PRIs) in Nigeria. Specifically, the enquiry focused on the main forms of institutional collaborations between the various actors in the Nigerian biotechnological system of innovation, their interactions (both formal and informal), the factors that condition or limit them, and the main obstacles to inter-organizational learning and collaboration. Primary data was collected using semi-structured questionnaires and interview guides. We discuss the importance of inter-organizational interactions in the biotechnological system of innovation for pharmaceutical research in a developing context using PRIs as an example. Section 2 presents a summary of the nature of innovation in natural products drug research, with a primary focus on the main actors and interactions in the process. Section 3 assesses the main role of PRIs as knowledge centers within the biotechnological system of innovation and, using field-level data, presents an overview of public research institutes in Nigeria. Section 4 contains a critical analysis of the role of PRIs in Nigeria and the primary factors that impinge on their effectiveness. Section 5 contains the conclusions.

2. NATURE OF (BIO)PHARMACEUTICAL RESEARCH: THE MAIN ACTORS AND INTERACTIONS

For purposes of this paper, (bio)pharmaceutical research is taken to mean pharmaceutical research that has integrated modern biotechnological processes into its domain, whether for research or the development of products (Ramani, 2002, p. 381). It has been increasingly acknowledged in recent years that several factors play a major role in (bio)pharmaceutical research, such as risk and uncertainty, the large time frames that may lapse until a marketable product is discovered, and the specialization required at each stage of the R&D process.

2.1. Risk, Investment and Uncertainty, and the Stages of Innovation

Although there are no direct estimates of (bio)pharmaceutical investments, several estimates exist regarding pharmaceutical R&D investments, the total time required to develop a marketable product, and risk and fall-out rates within the pharmaceutical R&D process. A recent study by the Tufts Center (2001) that was sponsored by PhRMA revealed that the average cost of developing a pharmaceutical drug in the USA has risen from US $54 million in 1979 (in 1976 dollars) to US$231 million in 1991 (calculated in 1989 dollars) and to US $802 million in 2001.[3] But there are other estimates that arrive at a total as low as US$ 200 million (OTA, 1991). Evidence suggests that the costs of pharmaceutical research depends heavily on several factors, such the place where the drug development and clinical trials take place, the costs of meeting regulatory approval, and so on. Many variations in estimates come from the fact that these assumptions are not uniform across the board.

Pharmaceutical research is also prone to high fall-out rates. Recent studies of drug research worldwide indicate that it is probably realistic to estimate that in order to produce one compound for clinical trial, over 100,000 compounds may need to be screened (Gehl Sampath, 2005). In any given scenario, the chances of discovering a useful commercial drug are enhanced if initial natural product extracts are exposed to as many screens as possible (Gehl Sampath, 2005). Similarly, on the question of time frames, it is generally estimated that it may take between 7-18 years from the start of any R&D program to a marketable product (ten Kate and Laird, 1999).

[3] Tufts Center for the Study of Drug Development (2001) estimate, cited in Dutfield (2003), p. 91.

2.2. Interactions in the Innovation Process[4]

Broadly speaking, (bio)pharmaceutical research can be divided into four main phases: screening, secondary screening, product development and clinical trials. Although biotechnological techniques useful to pharmaceutical research were first developed in the 1970s, they remained relegated to university laboratories for a long time after their initial successes. Several large pharmaceutical firms remained on the periphery of this development (see Powell, 1996), mainly due to the specialized skills required to venture into biotechnology-based research. This created a foundation for the establishment of inter-organizational collaboration between large pharmaceutical firms, which historically conducted all their research in-house, and smaller science-intensive enterprises (the small and medium enterprises, also known as dedicated biotechnology firms, or DBFs) for specific biotechnology-related services. As a result, several biotechnology firms were "entrepreneurial spin offs" started by successful university scientists or researchers ("entrepreneurial academics") and maintained very close contacts with researchers in PRIs and universities (Bartholomew, 1997; also see Powell, 1996, for an account of the intense academic culture in DBFs).

Relative strengths and competencies play a key role in maintaining collaborative arrangements between various actors over time in biopharmaceutical research. The SMEs and DBFs have innovative, leading-edge technological skills and are highly competitive in offering biotechnology-based services (Lerner and Merges, 1998). Pharmaceutical firms are better equipped to handle higher risks; they have the financial means and marketing infrastructure to do so. Similarly, universities and PRIs are involved in a range of contract research and collaborative research arrangements with the industry in the research and patenting stages (Chiesa and Toletti, 2004). Although there are several motives for interactions between industry/university/PRIs, the most important ones are the provision of additional funds for specific forms of biotechnology-based research and knowledge exchange through collaborative research arrangements (Meyer-Krahmer and Schmoch, 1998).

2.3. Policies and Institutions that Condition Interactions: Recent Experiences

Clearly, country-specific contexts shape innovation patterns and technological capabilities (see Lundvall, 1992; Nelson, 1993). The system of innovation for biotechnology-based drug research discussed in Section 2 is predominantly the USA model. Although it has its own strengths and weaknesses (see Bartholomew, 1997 for a discussion), the American model has provided a basis for policy interventions designed for promoting/rectifying critical gaps in interactions between organizations in several other countries.

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[4] This section is based on Gehl Sampath, Padmashree: *Regulating Bioprospecting: Institutions for Drug Research, Access and Benefit-Sharing*, UNU Press, 2005.

For example, a trend towards government-initiated coordination is evident in such countries as the UK, Germany and Japan, which have superior universities and PRIs involved in biotechnology research and yet show laxity in interaction intensity between the various actors in the biotechnological system of innovation (Bartholomew, 1997). In the UK, the government is trying to promote technology diffusion between industry, universities and PRIs, as well as enhance the commercial orientation of academics through several independent agencies. Germany, on the other hand, is pursuing a systematic policy-intervention strategy that aims to provide incentives for improving interactions between universities, research institutes and industry (Ibid). This strategy is also focusing on increasing the commercial orientation of research in universities and research institutes through greater collaborative research with industry and increased capital availability (Ibid.). Through these efforts, the "second revolution" of universities and research institutes is being ushered in.[5] Other policies, such as intellectual property policies relating to biotechnological innovations are also being promoted, based on their role in protecting drug industry investments and as an incentive for "entrepreneurial academics" in universities and PRIs (Arora, 1995; Jaffe, 1999).

Several other countries have followed suit in recent times, in efforts to design structured policy interventions to achieve similar ends. According to Oliver (2004), Israel's policy strategy on biotechnology has also focused on easing the commercialization of academic research. To enable this, the government of Israel pursued three main initiatives during the 1990s: cushioning start-up companies through the creation of incubation units; the creation of high-tech resource supplies for universities, research institutes and start-up companies; and the improvement of links between industry and academia (Oliver, 2004, p. 584).

Following on from the above, sectoral innovation systems tend to develop in different historical settings and follow different evolutionary trajectories and as such differ in four important respects (Malerba, 2004):

1. Sectoral Innovation Systems (SISs) are pluralistic in nature to varying degrees and based strongly on division of labour;
2. Component institutions make differential contribution to the innovation process, but differ significantly with respect to motivation and with respect to a commitment to, and the capability for, dissemination of the knowledge they generate;
3. They differ in size and in the mechanisms by which they accumulate knowledge; and,

[5] Literature on structural changes within universities classifies the first revolution of universities as one in which they were transformed from institutions of cultural preservation to institutions of new knowledge creation. The second revolution is a process where the focus is on translation of research into innovative products (Erkowitz *et al.*, 1998, cited in Oliver, 2004, p. 583-584).

4. They differ with respect to the intensity of connectivity between the components of the system and the type of mechanisms for interaction, such as:
    - The mobility of scientists and technology in the labour market;
    - Collaborative mechanisms (formal and informal) between enterprises;
    - Links between national institutions, such as universities and the productive sector; and
    - Informal mechanisms, which have become extremely effective in user-producer arrangements. To this end, networks have become a substitute for formal markets and for organizational integration.

3. BIOTECHNOLOGY IN NIGERIA: THE CASE OF PUBLIC RESEARCH INSTITUTES

Generally speaking, PRIs play two main roles in the development and maintenance of biotechnology-related competencies. First, they act as primary centres of innovation in the early periods of biotechnological innovation. In all countries that have been successful in developing biotechnological systems of innovation, PRIs and universities have been the centers of cutting-edge research. In the German system, for example, Bartholomew (1997) notes that the state-sponsored research institutes conduct "world class scientific research" that can be translated into industrial innovation.

Even when the biotechnological system of innovation is sufficiently developed, PRIs continue to perform a supportive role in two stages of biotechnology-based innovation – research and patenting. In research, they collaborate with dedicated biotechnology firms in providing the requisite knowledge base. PRIs also provide supportive services to universities – due to their specialized focus and advanced laboratory and human facilities – and thus act as coordinating centres for interaction between universities and industry in several instances.

3.1. Public Reserach Institutes in Nigeria: An Overview

In the biotechnology system of innovation (BSI) in Nigeria, universities and PRIs currently drive the process of change. PRIs are fully state-funded establishments devoted to research into the use of local resources with the objective of adding value through R&D and processing. The PRIs have different mandates and are found largely in agriculture, industry, and materials. The capacity of firms to exploit biotechnology innovation is at a very elementary phase in Nigeria mainly due to a weak private sector, low level of entrepreneurship and poor institutional capacity support for translating inventive effort into innovation. In this context, PRIs have been instrumental in exploring the potential of biotechnology in the existing research base, although in a limited way. Five public research institutes were considered in the study: the The Sheda Science and Technology Complex (SHESTCO), National Institute for Pharmaceutical Research and Development (NIPRID), The National Veterinary Research Institute (NVRI), National Institute for Medical Research (NIMR) and National Center for Genetic Resources and Biotechnology (NACGRAB). The main aim of the study was to understand the nature and depth

of the biotechnology component of their overall mandate.[6] In what follows, we discuss them briefly.

The Sheda Science and Technology Complex (SHESTCO), Abuja, is a science village that was established by the Federal Government of Nigeria as a multidisciplinary R&D center in 1993. The main aims are to (a) initiate and promote rational and innovative uses of Nigeria's natural endowments; (b) provide a center of excellence for research and training focused on the socio-economic progress of Nigeria; (c) train and develop manpower in research methodology and programme formulation; and, (d) develop results of research for application in the areas of agriculture, health, industry and environment. The Complex has advanced laboratories in four main disciplines: nuclear research, physics, advanced chemistry and advanced biotechnology. The Biotechnology Advanced Laboratory (BAL) is meant to provide advanced technological facilities for research in the main sub-disciplines of biotechnology – agricultural, medical, industrial and environmental. SHESTCO is an advanced laboratory devoted to biotechnology, but the organization is still relatively young and, unlike NIPRID, it has so far not produced notable products.

National Institute for Pharmaceutical Research and Development (NIPRD) was established in 1987, based on the recommendation of the Pharmaceutical Society of Nigeria (PSN) and by the FGN as an agency under the ministry of Science and Technology. The primary mandate of the Institute is to exploit local raw materials – through the application of modern scientific research and development methods – into high quality pharmaceutical grade raw materials, drugs and biological products for the management of tropical diseases and other global ailments.

The National Veterinary Research Institute (NVRI), Vom, can be traced back to 1913, when West Africa suffered its first major *Rinderpest* infestation. What started as a Veternary Department to deal with the problem was later moved to Vom. With an expansion in mandate and policy support, it was first renamed as the Federal Department of Veterinary Research and then as NVRI. Today, the principal mandates of the institute include: (a) conducting research into all aspects of animal diseases, their treatment and control; (b) developing and producing animal vaccines, sera and biologicals to meet national demand; and (c) training intermediate manpower in veterinary laboratory technology and animal health and production technology.

National Institute for Medical Research (NIMR), Yaba, was established in the 1940s as a West African initiative, but is now a federal institute that conducts research and carries out studies

[6] The statistical analysis on NAGRAB and NIMR are not included. In the case of NAGRAB, only one questionnaire was filled by the chief executive while we could not sample NIMR. NVRI and NIPRID each filled in 10 questionnaires, whereas 7 questionnaires were administered in SHESTCO.

that influence health policy-making in Nigeria. In its latter role, NIMR serves in an advisory capactiy to the government. The institute has five major departments – biochemistry, microbiology, molecular biology and genetics, public health and clinical sciences.

National Centre for Genetic Resources and Biotechnology (NACGRAB) was established in 1987 by Nigeria's Federal Ministry of Science and Technology to act as the center of focus in the country for research, data gathering and dissemination of technological information on matters relating to the utilization of genetic resources, conservation and biotechnology. It is also involved in the development and servicing of the activities of the National Committee on Naming, Registration, Release of Crop varieties and Livestock Breeding. To date, NACGRAB has evaluated and characterized exotic and indigenous plant germplasm wihtin the countru. It has also undertaken exploration and collation of endangered plant species. It has collected about 25 lost lines of *Vigna unguiculata* from International Institute for Tropical Agriculture (IITA). It has currently a total collection of about 12,000 plant species, maintained either as seed in cold-storage rooms or in the field (in field gene banks).

3.2. Results of the Survey

Of the five PRIs, NVRI, NIPRID, SHESTCO and NIMR are all involved to varied extents in medical research, depending on their institutional focus and specialization. As Table 1 shows, NAGRAB concentrates exclusively on the preservation of Nigeria's genetic resources, NVRI devotes most of its attention to animal-based agricultural research, NIPRID focuses on medical research, particularly on ethno-medicine; and, true to its mandate, SHETSCO's activities span the three areas of bioprocessing, or industrial, agricultural and medical biotechnology.

Table 1: PRIs Area of Focus (%)

Institutions	Industrial research	Agricultural research	Medical Research	Others*
1. NAGRAB[7]		100.0		
2. NVRI	10.0	90.0	10.0	
3. NIPRID	10.0		70.0	30.0
4. SHETSCO	71.4	57.1	71.4	

Source: INTECH Field work (2004).

* The category "Others" includes various forms of traditional medical research.

[7] The questionnaire by NAGRAB was filled in by the director of the agency and is the only place where we administered only one questionnaire.

The use of biotechnology tools in research activities of these institutions is, understandably, shaped by their respective specializations (See Table 2). Bioprocess technologies are widely applied at NIPRID and SHETSCO (57.2% and 60% of activity, respectively) whereas NIPRID devotes its financial resources to recombinant DNA techniques (20%) and molecular diagnostics (61.3%) and SHESTCO relies on tissue culture. Our study confirms the results of earlier studies focusing on agricultural biotechnology in Nigeria (Alhassan, 2000), which indicate that in agricultural research, the use of cell and tissue culture is more common than the use of bioprocessing and DNA techniques.

Table 2: Biotechnology tools and areas of work

Activities / **Institutions**	Percent of Financial Resources Devoted	Average Number of Researchers	How long work has gone in this area? (years)	% of your activity in 2003
NIPRID				
Cell and Tissue Culture	17.5	3.0	3.0	11.3
Recombinant DNA	20.0	3.7	5.5	33.3
Molecular Diagnostics	61.3	12.3	8.3	
Bioinformatics				
Bioprocess				57.2
SHETCO				
Cell and Tissue Culture		2.0		33.3
Recombinant DNA				6.7
Molecular Diagnostics		2.0	8.5	
Bioinformatics				
Bioprocess				60.0

Source: INTECH Field work (2004). Column 1 should add up to 100%; column 2 is the mean number of researchers.

The major activities carried out by the PRIs were surveyed under the categories of: research, teaching, consultancy, production, testing and laboratory services, contract manufacturing and others. Although the research institutes indulge in other activities such as consultancy, most of their time is spent on research (Table 3).

Table 3: Share of time among activities in percentage

Activities / Institutions	Research	Teaching	Consultancy	Production	T&L services	Contract Manu.
NACGRAB	40.0		20.0	40.0		
NVRI	44.8	10.1	2.2	22.4	0.6	19.9
NIPRID	58.6	2.7	14.7	16.6	1.8	5.6
SHETCO	49.5	13.5	1.2	18.5		17.2

Source: INTECH Field work (2004). Row percentages should add up to 100%.

Across the PRIs, our survey also shows that major efforts and resources seem to be concentrated on screening and secondary screening activities (30% to 68.3%). As such there is no statistically significant difference between institutes, meaning that all the PRIs are engaged uniformly in this activity. However, there are significant differences in the process/product development stage. Only two of the institutes – NVRI and NIPRID – are involved in production activities. NIPRID is active in producing an anti-sickle cell drug called Niprisan; NVRI is involved in vaccine productions, although on a limited basis for regional and national clients.[8] Once again, the reason for SHETSCO's lack of involvement in production may largely be due to the fact that it is a fairly young organization.

[8] The *Bacterial Vaccine Production Department* of NVRI is responsible for the production of various bacterial vaccines for the use in the control of livestock and poultry diseases. These vaccines include Anthrax Spore Vaccine, Black Quarter Vaccine, Contagions Bovine Pleuropneumonia Vaccine (live) wet & dry, Contagions Bovine Pleuropneumonia Vaccine (live) freeze dry, Contagion Bovine Pleuropneumonia Vaccine – Inactivate, Haemorrhagic Septicaemia vaccine, Fowl Typhoid Vaccine (wet and dry forms), Fowl Cholera Vaccine, BBG Vaccine, Hantavac Vaccine and the Vomac-3 Vaccine.

4. PATTERNS OF INTERACTION IN THE NIGERIAN BIOTECHNOLOGICAL SYSTEM OF INNOVATION: A CRITICAL ANALYSIS

The study found that, whereas several formal and informal modes of interactions existed, the main factors that limited inter-organizational collaboration are *a lack of*: technological capabilities, concerted policy interventions to foster access to information, and incentives to researchers to collaborate. These are discussed in detail below.

4.1. Lack of Scientific Expertise and Technological Capabilities

The survey showed that the predominance of screening and secondary screening activities across institutes involved in drug research is attributable to two factors (our survey reveals the same in the case of universities). First, a lack of finances hinders the capabilities of researchers to acquire requisite facilities even to perform screening satisfactorily. Several researchers interviewed confirmed the lack of finances to even buy an adequate number of protein targets to conduct mechanism screens. The lack of finances also hinders the the acquisition of specific skills through, for instance, training in advanced laboratories (often available only outside the country) to conduct the higher stages of research. Lack of finances at the governmental level to fund research and the poor remuneration of scientists is also cited as a factor that tends to play a role in the continuous migration of skilled people from Nigeria to the West. As a result of lack of finances for research, specialized capabilities are systematically absent in the various PRIs; researchers who wish to pursue their research efforts to the next stage tend to face severe constraints. Our survey revealed that the only exceptions to this were researchers who had succeeded in receiving individual grants to perform parts of their research in laboratories abroad, where the requisite technological capacities were available.

Second, concerted efforts to enhance technological capabilities through a competitive process have been thwarted by a lack of government funds and support (most respondents complained about the inadequacy and difficulties in obtaining government grants). Partly due to the problems in providing up-to-date facilities and research funds, the most talented university graduates either do not show interest in pursuing research careers within Nigeria, or those who do and are very good choose to do so in developed countries. The phenomenon of scientific labour migration was exacerbated in the 1980s due to the severe devaluation of the national currency and decline in scientific infrastructure. One factor that warrants mention in the context of up-to-date facilities is the problem of basic infrastructure. Most researchers complained of irregular power supply, out-dated equipment and lack of water facilities. Even SHESTCO's

relatively advanced laboratory facilities are only partially completed, due to consistent under-funding of the Complex.

Presently, 90% of the research funds (excluding salaries and recurrent funds) available with the PRIs are from international sources, with only 10% from the Nigerian government. The main sources of funds are United Nations agencies, universities and government laboratories in developing and developed countries, such as the National Institute of Health, USA; the Institute of Human Virology, USA (for collaborative work on the HIV-1 vaccines project); the US, Center for Disease Control and Prevention (CDC), USA; the Robert Koch Institute, Germany; the Council for Scientific and Industrial Research (CSIR), India; the Central Drug Research Institute, India; and the London School of Hygiene and Tropical Medicine, UK. Several other international agencies, such as the Ford Foundation, the Carnegie Foundation and the USAID also provide grants for such research collaborations. The grant money is used to buy laboratory equipment and chemical agents that are required for conducting research. These are currently the only sources of funding, and they are not sufficient to cover all research expenses. Several research institutes complained that their ability to conduct mechanism-based screens is curtailed by the fact that the funds do not suffice for the purchase of a wide variety of protein targets and inhibitors. As a result, all PRIs (except NVRI) place a very high importance on foreign funds, although on a comparative scale (See Table 4).

Table 4: Intensity of local and foreign collaborations (scale 1-5)

Institutions / Type of collaboration	NAGRAB	NVRI	NIPRID	SHETSCO
Local	2.00	1.80	2.40	2.69
Foreign	3.00	1.40	2.80	2.86

Source: INTECH Field work (2004). The table is indicative of collaborative intensity where 1=very low, 5=very high.

4.2. Lack of Coordinated Policy Interventions

Policy intervention in Nigeria in the field of biotechnology is constantly evolving. NABDA, an agency that has been set up by the Nigerian government to coordinate policies in this regard, is in its infancy. NABDA has the mandate of: (a) ensuring proper and effective coordination of biotechnology development in Nigeria; (b) encouraging the development and application of biotechnology-based products and services; (c) establishing well-equipped biotechnology

facilities for training, research and development in selected locations in Nigeria, including human resources; (d) stimulating biotechnology entrepreneurship to effect rapid commercialization of biotechnology research and development products; (e) developing strategic partnerships between all stakeholders within and outside Nigeria; and (f) ensuring sustained and adequate funding of biotechnology research and development.

Nigeria also has several other agencies – like the Nigerian Natural Medicine Development Agency (NNMDA), the state boards for traditional medicine, and the Nigerian Agency for Drug Approval and Control (NAFDAC) – which perform various roles in the innovation process. Presently, many of the competencies of these institutions are overlapping and, in some cases, the institutions are also overwhelmed by the magnitude of the tasks that lie ahead of them. For example, the NNMDA promotes the standardization and efficacy of natural medicine in Nigeria, but its interactions with other agencies involoved in biotechnological innovation in the country is limited. The NAFDAC is overwhelmed with its responsibilities in the sense that it is hard pressed to control the efficacy of natural medicine and related products in Nigeria. A different agency that coordinates the efficacy of natural medicine related products may be required.

The resulting lack of policy coordination is largely to blame for the duplicated efforts across the various PRIs in their activities (in many cases, our survey revealed that researchers were not even aware of the existence of similar activities in other institutes/university departments across the country).

More importantly, concerted policy intervention may be able to foster fruitful interactions between PRIs and several other counterparts of the Nigerian biotechnological system of innovation, such as traditional practitioners, hospitals and firms (See Tables 5 and 6). NVRI rates universities as the only collaborator above average and has very little to do with hospitals, industry associations and traditional medicine practitioners. The same applies to NIPRID, which collaborates with universities far more intensely than do SHETSCO and NVRI (3 on a scale of 1-5).[9] The way collaboration has changed over the last five years shows the same pattern; there is no notable difference among the PRIs. The forms of collaboration include information exchange, formal and informal meetings, joint publication, and the exchange of scientists. NVRI rates meetings, joint publications and the exchange of scientists above others, but is still below average. The other two PRIs rate these forms of collaboration fairly low.

[9] For instance, SHESTCO is presently conducting a project on 'Interdisciplinary Research on Hepatitis viral subtypes and disease epidemiology in Nigeria' in collaboration with National Hospital, Abuja and the National Mathematical Center. The project aims to improve the diagnosis, management and prevention of hepatitis and associated biochemical manifestations.

Table 5: Intensity and Partners in Collaboration (scale 1-5)

Institutions / Collaborators	NAGRAB	NVRI	NIPRID	SHETSCO
PRIs	5.0	2.0	1.8	2.57
Industry associations	4.0	1.4	1.6	1.72
Universities	None	2.7	3.0	1.86
External/private institutions	4.0	1.1	2.1	1.72
Hospital and health centres	None	1.0	2.3	1.14
Traditional Medicine Practitioners	1.0	1.0	2.7	1.0
Others	3.0	0.7	0.5	0.14

Source: INTECH Field work (2004)

Table 6: Changes in Collaboration with actors (in the last 5 years)

Collaborators / Institutions	Firms	Universities	PRIs	Laboratories
NAGRAB	1.00	1.00	1.00	5.0
NVRI	1.50	2.3	1.90	1.40
NIPRID	1.60	2.4	2.60	1.10
SHETSCO	2.86	2.86	1.86	1.29

Source: INTECH Field work (2004)

4.2.1. Statistical Results

In order to obtain further insight into the dynamics of learning in an inter-organizational context, we analyzed the data using probit regression, prefered over ordinary least square (OLS) analysis because the dependent variables are ranked variables. The first two dependent variables are proxies for internal organizational capacities for product and process development, while the last variable represents physical capacity for carrying out research ("investment in new laboratoty facilities"). The independent variables were selected based on the earlier univariate analysis that signalled to us which factors tend to be influential.

The parameter estimates and the corresponding t-statistics in the first equation (Model 1: M1, Table 7) shows that two variables – human capital (% of PhDs) and foreign collaboration – emerged as significant in determining the internal capacity for product development. For Model 2, internal R&D capacity for new process development, three variables – the percent of PhDs, external funding, and foreign collaboration – emerged as significant. One of the most poignant

observations that we made in the course of this study is the state of PRI laboratories which, due to official neglect, had deteriorated during the last decade (although considerable efforts have been made by the present government to rebuild the infrastructure). It is for this reason that we investigated the current efforts on laboratory investments, represented by the proxy in Model 3, Table 7. In this case, four variables are significant – research as a share of overall activity, percentage of PhDs, foreign collaboration, and collaboration with firms. The first variable - ,research as share of overall PRI activity - is significant but with a negative coefficient sign is indicative of the inverse relationship between activities that are carried out in the laboratories and the nature and magnitude of investment. In other words, investment decisions might not be directly related to what scientists prefer to do as such decisions tend to rely significantly on external aid and consultancies to develop the facilities. The quality of human capital, particularly the proportion of PhDs, emerged as expected as significant and with a positive coefficent sign, indicating a direct relationship between the level of investment and the quality of human capital. Evidently, those research institutes established to attenuate the limitations experienced in university research will face severe difficulties in the future if the current and continual drain of high-level skills is not halted. Foreign collaboration, as well as collaboration with firms, are significant. Domestic funding of research has been limited and quite often relies on politically-driven annual budgetary processes. It is for this reason that PRIs are starved of funds for a large part of the time and tend to rely on foreign grants and are often tied down by such aid - aid that is meant for very specific activities that may be different from the mandates of individual PRIs. Not suprisingly, collaboration with firms carries a small and negative coefficient, confirming what the univariate analysis earlier revealed, that there is little collaboration with domestic firms.

Table 7: Probit Estimates of Determinants of PRIs Performance

Dependent Variables	**Model 1: Internal capacity for Product development**			**M2: Internal R&D capacity for New Process development**			**M3:Investment in New Laboratory Facilities**		
Independent Variables	Coefficient	T-Value	Sig	Coefficient	T-Value	Sig	Coefficient	T-Value	Sig
1. Research as Share of Activity	.000781	-.927	.354	-.0013	-1.563	.1181	-.000377	-2.194	.0282
2. Human Capital (% of PhDs)	.00148	1.907	.0566	.00188	2.471	.0135	.00346	2.719	.0065
3. External funding and aid Q21B	.000134	.209	.8346	.00159	1.932	0.053	.000174	1.305	.192
4. Foreign collaboration Q28-gen	1.580	2.192	.0284	1.224	2.021	.0433	.2099	2.567	.0103
5. Q42E: collaboration with firms	.000951	1.274	.2028	-.000753	-.988	.3232	-.000306	-2.103	.0355
6. Q19 : Research on local problems	.00436	.611	.5415	.000803	.996	.3196	-.000127	-.892	.3722
7. Log likelihood	-11.319			-11.306			-1.9093		
8. significance level	.07037			.0133			.23225-04		

Source: Estimated from UNU-INTECH survey data.

In general, collaborative research and informal contacts are rated higher than contract research while studying PRI-industry interlinkages in the case of biotechnology. This is because they allow for a bi-directional exchange of knowledge, in contrast to the uni-directional export of information associated with contract research (Meyer-Krahmer and Schmoch, 1998, p. 841). But in our survey, NAGRAB is the only institute with a high rate of collaboration with the industry, whereas NIPRID and NVRI devote a significant amount of time to consultancies and contract manufacturing (compare Tables 6 and 5). This is an important reason for the lack of product orientation in the research efforts of PRIs. Another problem in establishing industry-PRI collaboration in Nigeria is that the private sector for drug research is weak, and is itself in need of support structures for finance and technological capacity building.

4.3. Lack of Adequate Incentives to Motivate Nigerian Researchers

Academic entrepreneurship in biotechnology can be promoted through various forms of incentives, such as (a) involvement in collaborative research that can foster the mobility of labor between research and industry, (b) consultancy possibilities to augment income, (c) patenting

possibilities and (e) full-scale commercialization of research results (Altonen, 1998). But institutional rigidity that is generally common to PRIs and universities across countries has resulted in an environment with a pervasive lack of institutional incentives to researchers in Nigeria. While the scope for commercialization exists, success has been limited in the Nigerian case to only collaborative research and consultancies. For instance, the study on the biochemical structure of some of the active ingredients of NIPRISAN was conducted with assistance from a German laboratory. SHETSCO has received consultancy money from one of the state governments in Nigeria to carry out tissue culture experiments on plantain, a local staple crop. However, only NIPRID has patented and carried out full commercialization of its sickle cell drug, niprisan, in collaboration with an American company called Xechem. Much of the work done by NVRI had been considered a public good and not patented.

The Nigerian research culture has been adversely affected over the past decades by several factors. There has been a gradual decline in investment in research activities due to economic problems in the country. Consistent diversion of funds from tertiary education into primary education on the advice of multilateral institutions has led to a decay of the research system. Finally, the expanding university system (which added 13 universities in the five-year period of 1970 to 1975) led to an explosion in student enrollment that was not met with a commensurate increase in research infrastructure. These factors add to the rigidity of the system and its inability to adapt to dynamic prospects brought about by new technologies.

The previous sub-section highlights some reasons for the lack of collaboration between industry and research institutes. In addition, researchers are very often unaware of the intellectual property dimensions of their research. In cases where they are aware, there seems to be a concern for immediate tangible gains (through publications of research results in international journals that may win them them recognition and subsequent fellowships for short- or long-term stays in foreign laboratories), instead of patent protection that may be more useful in the longer run for the biotechnological system of innovation. Both a lack of venture capital or other such sources of private finance, as well as an absence of risk-taking attitudes among researchers, contribute to the dearth of a culture of ‘academic entrepreneurship’.

5. CONCLUSIONS

This paper has analysed the importance of inter-organizational interactions in biotechnology-based drug research in Nigeria, using PRIs as an example. Interactions between PRIs and a variety of actors in the biotechnological system of innovation, namely firms, universities, traditional medicine practitioners, hospitals and health centers, industry associations, and external institutions were analysed.

The study shows that, whereas PRIs in Nigeria have been instrumental in exploring biotechnological research and its potential for agricultural and medical sectors, their capacity to do so has been constrained by several factors. Active research has been slow due to *a lack of*: technological facilities; a large number of qualified personnel; and collaborative research with all other actors in the biotechnology system of innovation.

The resilience of the research system is evident in its capacity not only to survive, but to explore newer technologies mainly on the basis of limited international support. Our study found that several of Nigeria's research institutes, like NIPRID and NIMR, also have clinical facilities. Whereas NIPRID conducted clinical development of NIPRISAN using its own facilities, NIMR's capacity in this regard is also significant. Additionally, other facilities, such as an all-purpose essential oils extraction pilot plant for the production of NIPRISAN and other drugs was funded by the FGN, UNDP, and UNIDO in the late 1990s. This has become an essential facility that the sector as such, and PRIs in particular, rely on despite the usual problems in infrastructure, such as frequent power outages and occasional breakdowns due to the lack of spare parts and components.

The two most critical aspects for biotechnological systems of innovation to develop are adequate funding and lack of collaboration between various actors to generate interactive learning. To recap the discussion in Section 2 on drug research, funding is important to promote private sector activity as well as to promote premier research activities in universities and public research institutes. Funding venues and interactive collaboration based on actor specialization also play a major role in managing the risk and uncertainty inherent in drug innovation processes. The study shows that funding is sporadic and low – mostly PRIs rely completely on foreign funding, which may or may not continue beyond short- or medium-term horizons. Furthermore, all potential channels of interaction that could otherwise provide positive impetus to biotechnological innovation are constrained. Industry involvement is low, owing to the fact that the private sector for drug research in Nigeria is itself in need of basic support, including sources of finance (e.g., venture capital), better infrastructure, and technology diffusion

activities that can enhance their internal capacity. There is also an historical lack of collaborative interactions between industry and public research. Interactions between the various PRIs is itself weak as a result of lack of information and absence of incentives amongst researchers to indulge in joint research. PRIs also do not collaborate sufficiently with traditional medicine practitioners and hospitals. Due to these problems in local collaboration and funding, the PRIs rely to an extraordinary extent on external funds.

The main issue for policy intervention, based on the results of the study and the experience of other countries, is one of encouraging interactive learning. In the Nigerian context, such policy interventions should be aimed at two different levels. The first relates to improvement of incentives for academic researchers, through a general 'up-lift' of funding possibilities, a provision of inducements (such as increased financing and improved industry collaboration) that promote an industrial orientation in advanced research, and enhanced coordination between various research initiatives to avoid duplication and to promote joint research. Promoting interorganizational interactions between the various PRIs itself can go a long way towards strengthening existing biotechnology capabilities, since the PRIs have complementary competencies. While NIPRID and NIMR have very good facilities for pre-clinical and clinical development, SHESTCO has advanced biotechnological techniques for recombinant DNA and genomics, and NACRAB has an extremely diverse gene bank to source novel compounds for screening purposes.

Improvement in the academic and research environments alone will not be sufficient to bring about sustained development in the biotechnological sector. Therefore, a second level of policy intervention should be aimed at other actors in the biotechnological system of innovation – including firms, universities, practitioners of traditional medicinal, and hospitals. Mediating variables in the case of biotechnology clearly include an active private sector and a thriving culture for academic research in the various sub-disciplines (Lehrer and Asakawa, 2004). This should be the emphatic focus of policy intervention in Nigeria. Policy interventions should encourage the movement of skills between various organizations – such mobility of labor can be very fruitful. In the Nigerian instance, the production of a typhoid vaccine was facilitated through the movement of a researcher from the NVRI into the university system. Policy interventions at both levels, whether implemented through NABDA completely or by way of many different agencies, must be well-coordinated and suited to local habits and practices.

REFERENCES

Arora, Ashish. 1995. "Appropriating Rents from Innovation: A Historical Look at the Chemical Industry," in Albach, Horst and Rosenkranz, Stephanie, eds., *Intellectual Property Rights and Global Competition: Towards a New Synthesis,* Berlin: WZB Publications, 1995, 339-368.

Bartholomew, Susan. 1997. "National Systems of Biotechnology Innovation: Complex Interdependence in the Global System," *Journal of International Business Studies,* 28:2: 241-266.

Chiesa, Vittorio and Toletti, Giovanni. 2004. "Network of Collaborations for Innovation: The Case of Biotechnology," *Technology Analysis and Strategic Management*, 16:1: 73-96.

Cohen, W. and Levinthal, D. A.. 1990. "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, 35: 128-152.

Dutfield, Graham. 2003. *Intellectual Property Rights and the Life Science Industries*, Ashgate Publications.

Edquist, Charles. 1997. *Systems of Innovation Technologies, Institutions and Organizations,* London and Washington: W.W. Norton Publishers.

Foray, Dominique. 1995. "Knowledge Distribution and the Institutional Infrastructure: The Role of Intellectual Property Rights," in Albach, Horst and Rosenkranz, Stephanie, (Eds), *Intellectual Property Rights and Global Competition: Towards a New Synthesis,* Berlin: WZB Publications,. 77-118.

Freeman, Christopher. 1988. *Technology Policy and Economic Performance: Lessons from Japan*, London: Pinter Press.

Halliday, R.G., Walker S.R., Lumley, C.E. 1992. "R & D Philosophy and Management in the World's Leading Pharmaceutical Companies," *Journal of Pharmaceutical Medicine,* 2: 139-154.

Lundvall, Bengt-Åke. 1992. *National Innovation Systems: Towards a Theory of Innovation and Interactive Learning*, London: Frances Printer.

Jaffe, Adam B. 1999. "The U.S. Patent System in Transition: Policy Innovation and the Innovation Process," Working Paper 7280, National Bureau of Economic Research, http://www.nber.org/papers/w7280, Cambridge,.

Lerner, Josh and Merges, Robert P. 1998. "The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry," *The Journal of Industrial Economics*, 46: 2: 125-156.

Madhok, Anoop and Osegowitsch, Thomas. 2000. "The International Biotechnology Industry: A Dynamic Capabilities Perspective," *Journal of International Business Studies,* 31:2, 325-335.

McChesney, J.D. 1996. "Biological Diversity, Chemical Diversity and the Search for New Pharmaceuticals," in Balick, Michael J., Elisabetsky, Elaine and Laird, Sarah, A., (Eds), *Medicinal Resources of the Tropical Rainforest – Biodiversity and its Importance to Human Health.* New York: Colombia University Press.

Meyer-Krahmer, Frieder and Schmoch, Ulrich. 1998. "Science Based Technologies: University-Industry Interactions in Four Fields," *Research Policy*, 27: 835-851.

Nelson, R. R. (ed). 1993. *National Systems of Innovation: A Comparative Study*, Oxford: Oxford University Press.

Office of Technological Assessment. 1991. *Biotechnology in a Global Economy*, OTA-BA-494, Washington, DC: US Government Printing Office.

Oliver, Amalya L. 2004. "Biotechnology Entrepreneurial Scientists and Their Collaborations," *Research Policy*, 33: 583-597.

Powell, W.W., Koput, K., Smith-Doerr, L. 1996. "Inter-Organisational Collaborations and the Focus of Innovation: Networks of Learning in Biotechnology," *Administrative Science Quarterly*, 41:1: 116-145.

Ramani, Shyama V. 2002. "Who is Interested in Biotech? R&D Strategies, Knowledge Base and Market Sales of Indian Biopharmaceutical Firms," *Research Policy*, 31, pp. 381-398.

Scotchmer, Suzanne. 1999. "Cumulative Innovation in Theory and Practice," Working Paper Series, Berkeley: University of Berkeley.

ten Kate, Kerry and Laird, Sarah A.. 1999. *The Commercial Use of Biodiversity,* London: Earthscan Publications.

Walsh, Gary. 2003. Biopharmaceuticals: Biochemistry and Biotechnology, West Sussex:Wiley and Sons.

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