RESEARCH & INNOVATION IN DEVELOPMENT

Introduction to concepts related to research for development

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Institut de recherche
pour le développement

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Résumé du rapport

D'après la liste des objectifs de développement durable de l'ONU, le secteur de la science, de la technologie et de l'innovation (STI) est un élément clef pour un développement inclusif et global. Les interactions entre la science et la technologie dans le processus d'innovation ont évolué d'un simple modèle linéaire à un cadre de Systèmes Nationaux d'Innovation. Ce dernier donne une grille de lecture pour expliquer les interactions complexes et multiples entre la science et la technologie, et ce dans un contexte institutionnel. Cependant, une croissance économique liée au STI nécessite une forte capacité nationale d'absorption, c'est-à-dire s'assurer que les connaissances étrangères en STI peuvent s'adapter aux spécificités locales. Ce dernier point implique la nécessité d'un travail commun et non d'un échange unilatéral. Ainsi, en s'engageant dans des collaborations Nord-Sud et Sud-Sud durables, les pays émergents ont la possibilité d'exploiter leurs STI dans **l'objectif d'un rattrapage développemental pendant le 21ème siècles**.

C'est pourquoi des pays tels que la France met en place des institutions d'aide au développement à l'instar de l'Institut de Recherche pour le Développement (IRD). L'IRD est une organisation gouvernementale de recherche française sous la tutelle du Ministère de l'Education Supérieure et de la Recherche et du Ministère des Affaires Etrangères et du Développement International. L'IRD encourage la croissance développementale des pays du Sud, à travers l'expansion de leurs STI. Cette collaboration Nord-Sud se traduit par des services visant les échanges d'informations, l'expertise consultative, l'aide et la formation dans la production et le management de STI.

Un des objectifs clefs de l'IRD est de promouvoir des partenariats unilatéraux et multilatéraux entre des organisations du Nord et du Sud pour résoudre des problèmes globaux qui nécessitent une amélioration des connaissances. En effet, ces partenariats renforcent les capacités STI, valorisent la recherche et assurent le transfert de technologie. Pour ce faire, l'IRD peut s'appuyer sur des Programmes Régionaux Multidisciplinaires, des Laboratoires Internationaux Joints, des Observatoires pour la Science de l'Univers et la Flotte de Recherche Océanographique.

Le bureau IRD chargé de superviser les projets institutionnels et de recherche en Afrique Australe est une base d'opération commune avec le CNRS et le CIRAD. Les projets institutionnels sous la tutelle de ce bureau tels que CAAST-Net Plus, ERAfrica, ESASTAP 2020, RINEA, sont tous financés par l'Horizon 2020 de l'Union Européenne renforçant ainsi la coopération UE-Afrique dans le domaine du STI. Les projets de recherches ont pour thème la prévention du VIH (TasP), les sciences marines et atmosphériques (ICEMASA) et la gestion de la terre.

Le secteur STI est fortement lié au niveau de développement des pays industrialisés et nouvellement industrialisés. Les économies émergentes commencent à entrer dans la communauté globale du STI avec la double visée de catalyser leurs rattrapages technologiques et de réduire leurs niveaux de pauvreté locale en améliorant leurs capacités STI dans l'agriculture, la santé, l'eau et l'environnement. Ces secteurs sont particulièrement importants pour les pays qui en sont au début de leur parcours développemental. En revanche, nous ne pouvons pas oublier certains éléments nécessaires pour mener une politique STI avec succès (aussi bien dans le Nord que dans le Sud) : améliorer du capital humain, stimuler une demande pour le savoir dans le secteur privé, assurer le soutien du secteur public pour le STI et garantir une infrastructure de Technologies d'Information et de Communication aux normes internationales.

Deux débats centraux du secteur STI sont examinés dans ce rapport :

- L'importance de la recherche fondamentale vis-à-vis de la recherche appliquée dans le développement d'un pays. Ce sujet est analysé en regardant l'évolution des modèles d'innovation et le rôle changeant de ces deux types de recherche à différents moments du parcours développemental.
- Le rôle joué par l'élite d'un pays pour un développement national lié au STI. Ce rapport examine ce sujet en associant le secteur d'éducation tertiaire faible du Sud (causé en partie par le changement de priorité par la communauté internationale vers l'éducation primaire) avec les élites prétoriales. Une autre source potentielle d'amélioration de l'éducation supérieure dans le sud est le modèle de diaspora pour valoriser les élites vivant en outremer : un secteur crucial pour créer une élite développementale.

La section suivante est focalisée sur la diplomatie scientifique comme outil pour promouvoir l'agrandissement des connaissances et l'implantation d'une politique étrangère concernée par la science et favorable à la science. Ce rapport prend en compte le rôle joué par la diplomatie scientifique dans les relations Nord-Sud et dans le développement des pays de ces zones. Nous prendrons la France et l'Afrique du Sud comme cas d'étude.

La dernière section de ce rapport examine plusieurs indicateurs utilisés dans le secteur STI pour en mesurer la production et la performance. Nous retrouvons deux types d'indicateurs :

- Indicateurs bibliométriques avec par exemple, le H index ou l'Impact-Factor nous donnent la possibilité de comprendre la performance scientifique au niveau individuel et collectif ainsi qu'au sein de revues scientifiques.
- Les indicateurs institutionnels et composites à l'instar du Global Innovation Index ou du Gross Domestic Expenditure on R&D nous donnent une image des activités STI au niveau national. Cette section se termine avec une comparaison des performances STI des pays africains les plus actifs dans le domaine – l'Égypte, le Kenya, le Nigéria et l'Afrique du Sud – avec l'utilisation d'un panel d'indicateurs.

En conclusion :

Le secteur STI est clairement une force motrice pour le développement du Nord et du Sud. Pour s'assurer que le Sud suit une trajectoire de rattrapage technologique, les pays émergents doivent concevoir des plans et stratégies de STI qui sont mesurables et qui exploitent les ressources de la communauté STI globale. Ceci ne peut qu'être fait en utilisant la diplomatie scientifique où le Sud s'intègre au sein de réseaux mondiaux de STI, s'implique dans les décisions politiques de ce secteur et identifie correctement les initiatives STI locales qui auront les plus grands retours sur leurs investissements.

Executive summary

Science, technology and innovation (STI) is a factor for global development which has been earmarked by the United Nations in its list of Sustainable Development Goals, as necessary in promoting sustainable and inclusive development. The understanding interactions between science and technology within the innovation process has changed from a simple linear model to a National Systems of Innovation framework; which explains dual spill-overs between science and technology within an institutional context. Innovation-driven growth necessitates a strong national absorptive capacity in order to adapt foreign knowledge and technology – gained through global scientific cooperation networks – to the country's local specificities. By engaging in sustainable North-South and South-South collaboration, emerging economies have the opportunity to harness STI with the goal of completing a developmental catch-up in the 21st century.

The Institut de Recherche pour le Développement (IRD) is an advanced governmental research organisation supervised by the French Ministry of Higher Education and Research and the Ministry of Foreign Affairs and International Development. The IRD undertakes to empower countries in the Global South – whose chosen growth driver is STI – through information sharing , consultative expertise, support and training in STI production and management. The organisation's role, focus and has been redefined numerous times through its existence; most recently in March 2015 where it adjusted its governance model and strategy to suit its renewed global outlook.

The IRD aims to promote unilateral and multilateral partnerships between organisations from the North and South to leverage their STI sectors in solving global issues that requiring a major advancement in knowledge; through capacity building, research valorisation, technology transfer. The research arm of the IRD's mission is centred around: Regional Multidisciplinary Programmes, International Joint Laboratories, Observatories for Science of the Universe and the Oceanographic Research Fleet.

The IRD office for Southern Africa is responsible for overseeing numerous institutional and research projects in the region, together with being a joint base of operations for the CNRS and CIRAD. The current institutional projects run by this office – CAAST-Net Plus, ERAfrica, ESASTAP 2020, RINEA – are all funded by the European Union's Horizon 2020 Framework and aim to strengthen EU-Africa STI cooperation by targeting different aspect of this multinational relationship. The research projects undertaken by the IRD in Southern Africa target fields such as HIV prevention (TasP), marine and atmospheric sciences (ICEMASA), and land management.

STI is strongly linked to the development levels of industrialised and new-industrialised economies. Emerging economies are beginning to enter the global STI community to catalyse their technology catch-ups; while contributing to domestic poverty alleviation by improving focussed STI capacities in agriculture, health, water and the environment. These fields are of particular importance to economies which are still in the earlier phases of development. However, there are particular factors which are necessary for a successful strengthen of national STI are common to both the North and South, these include: improving the human capital, stimulating demand for knowledge for commercialisation in the private sector, garnering support for STI from the public sector and ensuring that Information & Communication Technologies (ICTs) are up to the global standard.

There are two strong debates within the field of STI which are explored in this report:

- The question of whether basic research or applied research within the innovation process has a greater importance on the development of an economy. This topic is explored by looking at the evolution of innovation models and the changing roles that basic and applied sciences can play in various developmental stages.
- The role that elites play in STI-led development. This report investigates this topic by linking the South's weak tertiary education sector to predatory elites and the post-1985 shift in focus to primary education by multilateral organisations. The diaspora model to valorise the overseas-based elites is also discussed as a potential source of improving the higher education sector in the South; which is so critical creating a wider developmental elite.

This section is followed by a focus on the field of science diplomacy as a tool to promote knowledge growth and to implement foreign policy which is both informed by science and favourable to STI-led sustainable development. The current trend in this field is summarised by the EU Commissioner for Research, Science and Innovation, Carlos Moedas as the three O's: Open Innovation, Open Science and Open to the World. This report then examines of the role played by science diplomacy in countries in the North and the South by taking France and South Africa as case-studies.

The last section of the report discusses the various indicators used to measure STI production and performance. Bibliometrics such as the H-index and the Impact Factor allow us to understand scientific performance on the individual, group and journal level; while composite and institutional indicators such as the Global Innovation Index or Gross Domestic Expenditure on R&D allows us to assess STI activities at a national level. Finally, the top STI producers in Africa – Egypt, Kenya, Nigeria and South Africa – have their STI performances compared using a wide range of indicators.

STI is clearly a driving force behind the development of both the North and the South. In order for the South to pursue a sustainable technological catch-up; emerging economies need to have measurable STI plans and strategies that fully utilise the resources of the global STI community. This can be done by leveraging science diplomacy to allow the South to integrate the global STI networks and policy decisions; while correctly identifying and funding domestic STI initiatives with significant returns on investment.

1. INTRODUCTION

1.1. Background

The United Nations has recently updated its new priorities by releasing a list of its Sustainable Development Goals and has stated that "debates on how best to promote sustainable and inclusive development are incomplete without a full consideration of issues of science, technology and innovation (STI)" (ITU, et al., 2012). Science has been mentioned as a pre-condition for modern development and not a luxury as it is often perceived. This is due to the fact that scientific research forms the bedrock upon which technology and innovation are built. The literature on the effect of STI on economic development has been mostly centred around the experiences of developed economies and can be traced back to 1911 with Schumpeter's simple model of innovation. Further advances were made during the 1990s by Rosenberg and Freeman in describing a multi-directional interaction between science and technology in the innovation process. These academics were also the pioneers in describing the benefits of approaching the innovation process though the scope of National Systems of Innovation (NSI). This framework has become extremely important in shaping STI policy as it allows governments to define: institutional labour division in terms of basic and applied science, the public and private sectors, and the compulsory feedback and interactions between STI institutions.

Innovation-driven growth is not solely a playground for developed countries anymore, as many developing countries – most notably in South-Asia - have been able to achieve tremendous economic development in this manner. The early development process of countries relies strongly on the absorptive capacity of a country: it capability to imitate existing technology and adapt it to a local market. Scientific institutions serve the purpose of supporting learning processes and the diffusion of technology at the beginning of the catch-up process and must then adapt to the later stages of development where technology growth relies more heavily on scientific research. Beyond supporting the absorptive capacity of countries, scientific institutions have numerous secondary yet important functions such as: focussing industrial sector policy into areas of technology development that are feasible and reducing entry costs into these sectors; improving health services which has a positive knock-on effect on economic growth and creating agricultural processes that are adapted to the local ecological specificities of a particular country (Bernardes & Albuquerque, 2003).

Developing an absorptive capacity without having any sources of technology to adapt would render the investments fruitless. In order to ensure a continuous absorption of science and technology, emerging economies must make efficient use of scientific cooperation networks. These networks consist of private and governmental organisations and individuals involved in the research, technology and innovation development industry. Scientific exchanges between the global North and the global South are those which have been most influential in aiding emerging economies in their quest for knowledge. This relationship has changed over time: initially it was a one sided transfer of knowledge from the North to the South that was strongly based on colonial power relations; it has now matured towards a more mutualistic partnership paradigm, where knowledge flows are bilateral. If this inclusive approach to scientific exchanges were to permeate into the private sector and society as a whole, STI could very well be the defining factor for development in the 21st century.

1.2. Objectives

The objective of this report is to provide an introductory understanding of the role played by research and innovation in the development of emerging economies. The sub-objectives are to:

- Describe my employer, l'Institut de Recherche pour le Développement (IRD) in terms of its: status as an organisation, mission, history and the work it is involved in both generally and more specifically in the case of Southern Africa.
- Discuss concepts for research, innovation and development which include: the most suitable types of research for development, the roles of elites in uniting STI with development policy and scientific diplomacy.
- Investigate the various indicators used in research and innovation in development.
- Formulate a questionnaire and disseminate it to gather information from scientists involved in international scientific cooperation; in order to complement my bibliographic research.

2. METHODOLOGY

2.1. Bibliographic research

The information contained within this report was accumulated and adapted from a wide range of web-based sources. The University of Cape Town library and IRD databases were used to gather this material.

2.2. Questionnaire-based research

I asked participants on to fill in the questionnaire attached in Appendix 3. The questionnaire is web-based using Google Forms as the input platform, it was sent as a link via email to scientists involved in international scientific cooperation.

3. INSTITUT DE RECHERCHE POUR LE DEVELOPPEMENT (IRD)

3.1. Status

The IRD is an advanced governmental research organisation supervised by both the French Ministry of Higher Education and Research and the Ministry of Foreign Affairs and International Development. This joint tutelage allows the institute to access resources and tools that are both diplomatic and scientific in their nature; which let it to pursue its goals more efficiently than many other similar organisations.

3.2. Mission

The IRD's undertaking is to use the resources at its disposal to empower countries in the Global South that have chosen science and innovation as their primary drivers for development. This is done through facilitating ethical cooperation and partnerships between the South, the international scientific community and various international institutions in targeted multidisciplinary research programs and capacity-building policies to enact sustainable development in the South.

3.3. Description

The IRD is public science and technology establishment based in Marseilles, France; which delivers information, research valorisation, expertise, support and training in STI production performance. It uses its unique methodology in development research and know-how to promote the sharing of knowledge on a global level (IRD, 2016).

History

The IRD has its origins in the late 1930's, where France was trying to valorise STI in its colonial territories. The organisations leading up to Institute have experienced numerous changes in supervision, objectives, management structure and headquarter location. The now matured institute is engaging with the South in a more wholesome, ethical way than its predecessors by focussing on research partnership with developing countries.

3.3.1.1. Colonial period

- The Advisory Committee of Scientific Research for overseas France and the Higher Council for Scientific Research were created in 1937. Their mandate was to facilitate the coordination between national research institutions charged with organising "colonial science"; whose goal was to improve colonial efficiency and development.
- The Office of Scientific Colonial Research (ORSC) is created in 1943. The ORSC was supervised by the Secretary of State for the Navy and the Colonies and chaired by the Director of the CNRS. Its aim was to form a scientific corps through training specialising in the tropics and the formation of research centre networks in France's overseas territories.
- The ORSC is renamed twice through 1944 to 1953. First as Office of Scientific Research Overseas (Orsom) and then as the Office of Scientific and Technical Research Overseas (ORSTOM).

3.3.1.2. Independence of african countries

- ORSTOM receives new joint supervision in 1960 from the Minister of National Education and the Secretary of State for Relations with States of the community. The Office adapts its mission to promote basic research and a policy of scientific and technical cooperation with the South in the view of its development.
- During the period of 1960 to 1983, ORTSOM undertakes: the consolidation of its scientific organisation, the strengthening of infrastructure in Africa and other overseas provinces (DOM) and developed cooperation with South American, Southeast Asian and Arab countries.

3.3.1.3. Development research

- Reform of the Office in 1984 where it is renamed the French Institute for Scientific and Technical Research for Development and Cooperation, but retains its acronym ORSTOM. It is placed under the joint tutelage of Ministry of Research and the Ministry of Cooperation and given the status of EPST. Its mission is to make a lasting impact to the economic, social and cultural development of the South through scientific and technological research.
- ORSTOM becomes the IRD on 5 November 1998, experiencing operational reforms that split the institute into 5 scientific departments: environment, living resources, society and health, expertise and development and support and training of scientific communities in the South (IRD, 2016).

3.3.2. Research

The institute's research current focus is on the consequences of climate change, demographic trends and globalisation. Thematically, these issues can be discussed as: health, society, resources and the environment. This research is conducted by a variety of joint research units (UMR), international joint research units (UMI) and joint service units (UMS). In 2014, the IRD's combined 56 research units were able to produce 3825 scientific publications, 108 patents at a co-publication rate of 51% with partners from the South.

3.3.2.1. Regional Multidisciplinary Programme

The IRD makes use of Regional Multidisciplinary Programmes (PPR) as a base for research projects on a broad multidisciplinary research question. These instruments for programming support vast networks of scientific teams while catalysing regional research, training, innovation and project creation and financing between institutions from the North and the South (IRD, 2016).

3.3.2.2. International Joint Laboratories

International Joint Laboratories (LMI) are operational research structures located in common scientific facilities; which formalise the collaboration between the IRD and partners from the South on research projects, training and innovation.

An LMI is created around a precise scientific theme and a common platform with the aim of accumulating a critical mass of complementary competences applied towards converging scientific goals. These middle-term laboratories have the aim to become a national and international reference base for their chosen theme (IRD, 2016).

3.3.2.3. Observatories for Science of the Universe & the Oceanographic Research Fleet

The IRD is partnered with the Observatories for Science of the Universe (OSU) – internal university schools – which contribute to the advancement of knowledge in the fields of: astronomy, astrophysics, solid Earth, marine, atmospheric, surface and continental environment sciences. They deliver this through resource development and exploitation, gathering observational data, the conception of theoretical tools and the provision of a wide range of services related to their fields of expertise.

The French Oceanographic Fleet (FOF) is a joint service unit which is mandated to supervise the programmes of the ships and equipment of its members, coordinate investment policies and anticipate the renewal of the national fleet (IRD, 2016).

3.3.3. Partnerships

The pressing global issues that require a major advancement in knowledge mean that research partnerships are crucial in tapping into the variety of skills and expertise to solve these problems timeously. The IRD believes that development research completed with the use of partnerships will strengthen the South's scientific capacities and that of its economic research. These partnerships offer a chance for heightened international scientific competition in research and co-publication which leads to greater quality in research output. In line with this the IRD has developed a Partnership Charter for research in development which follows ten principles that promote fair, ethical and balanced partnership relationships to mutual benefit of countries from both the North and South (IRD, 2016).

3.3.3.1. Capacity building

The IRD stresses the need for the inclusion of capacity-building in its projects as the Institute believes in the dual spill overs which science can offer to development and vice-versa. Global scientific excellence depends on numerous crucial capacities which require specific skills which must be acquired in laboratories.

The Service Renforcement des Capacités – a unit within the IRD – aims to develop these skills in researchers, administrators and institutions with which it has partnered, through focussed and complementary programs.

These programs allow IRD partners to gradually integrate international research networks; as their projects are vetted from the bottom-up for the highest standard in scientific excellence through a series of rigorous and transparent selection procedures.

The IRD is constantly reassessing the needs and issues within the capacity building field in order to best position itself to its ever changing nature. This is done through diagnostic analyses and studies which help inform the IRD together with its current and potential partners of the challenges they could face with capacity building (IRD, 2016).

3.3.3.2. Valorisation & technology transfer

The IRD has a specific unit – la Direction de la Valorisation au Sud (DVS) – which deals with the valorisation of research from IRD and partner researchers. The unit does this through the development of intellectual property management activities, assisting the creation of innovative businesses, enabling transfers and partnerships with industry and providing consultancy and expertise services. The DVS facilitates collaborations with public or private actors through research contracts, technology transfers and feasibility studies (IRD, 2016).

3.3.3.3. Relations with regional and international organisations

The IRD is a major actor in European research for development, contributing to the dialogue of Europe in science and the necessity for coordination of research in Europe to better serve the Sustainable Development Goals. The IRD is a participant within the Horizon 2020 program (amongst many others) which allows it to work with the best European teams in research for development and increases the visibility of research output of its partners from the South by inserting them into European projects.

Europe is the main space in which French research organisations can collaborate and the IRD entertains bilateral and multilateral relations in this space through agreements with numerous other research and multilateral organisations. This allows the IRD to position itself and its teams within the best laboratories to continue research, capacity building and the valorisation with subjects that are important to the Institute.

3.4. IRD in Southern Africa

The IRD has been present in South Africa since 1995 and has since broadened its scope of action by interacting with actors in Angola, Botswana, Mozambique, Namibia and Zimbabwe. The IRD office based in Pretoria has recently become a joint base of operations of the CNRS and the CIRAD, which allows a stronger synergy between these institutions in Southern Africa. The IRD's 26 research units in the region, its many French and Southern African partners and its tools for international collaboration have allowed the Institute to lead successful projects with prominent universities and research institutions (IRD, 2016).

3.4.1. Institutional projects

The IRD office for Southern Africa is currently involved in 4 major institutional STI cooperation projects, which are all funded by the European Union's Horizon 2020 framework. These include CAAST-Net Plus, ERAfrica, ESASTAP 2020 and RINEA.

3.4.1.1. CAAST-Net Plus

CAAST-Net Plus is network of 26 European and African partner organisations that are building on the results of the CAAST-Net project (2008-2012).

This project aims to improve bi-regional STI cooperation on topics of mutual interest, particularly those related to the global societal challenges of climate change, food security and health. CAAST-Net Plus also has the goal of fostering discussion among stakeholders to improve the bi-regional cooperation process. This is done by gathering information, formulating and disseminating it in a manner that has an impact on the formal bi-regional STI policy dialogue process and on programme owners (CAAST-Net Plus, 2016).

3.4.1.2. ERAfrica

ERAfrica is a joint European-African project with the aims of promoting a refreshed and unified method of intercontinental collaboration and promotion in the fields of STI and sustainable development. Through ERAfrica, funding parties from 15 African and European countries developed the joint creation of necessary funding mechanisms and processes leading up to a first call for research proposals where all partners participated on an equal footing and where all national and institutional demands were adequately satisfied and all voices heard and respected.

These countries launched together a joint call for projects in three thematic fields encompassing three types of collaborative activities. The three thematic fields are:

- Renewable Energies: funding projects addressing renewable energy topics.
- Interfacing Challenges: funding projects which are conducted at the interface of key societal challenges where African and European collaboration stands to have added value.
- New Ideas: funding outstanding idea-driven projects generated in a bottom-up approach where the emphasis is placed on clearly evidenced originality and novelty of the idea, approach or expected outputs.

With a total amount of € 10.7 million available for funding the call generated 124 proposals of which 106 eligible proposals involving 560 organisations requested an amount of € 64.8 million. ERAFRICA selected 17 projects to be funded, 10 in the Interfacing Challenges theme, 5 in the New Ideas theme and 2 in the Renewable Energies theme. These selected projects represent a total amount of € 8.29 million and 65 institutions from 18 countries will jointly work together in these projects.

As 9 African institutions and 8 European institutions have the important role of project coordination the overall picture shows that ERAfrica indeed lives up to its aim of true partnerships (ERAfrica, 2016).

3.4.1.3. ESASTAP 2020

The ESASTAP 2020 project is a coordination and support action that aims at furthering the EU-SA bilateral STI cooperation, building on the work and results of three preceding actions (ESASTAP, ESASTAP-2 and ESASTAP+) and responding to the needs and recommendations at the policy dialogue level. The focus is on achieving the mandate of the JSTCC and that of the adopted Roadmap for EU-SA cooperation.

To meet its objectives, the ESASTAP 2020 is prioritising: research and innovation in areas of common interest (Horizon 2020, etc.), EU-SA policy dialogue, promoting the project to potential South African partners and the provision of a cooperation platform and of tools to remove obstacles that inhibit this cooperation (travel, funding and program restrictions) (European Comission, 2016).

3.4.1.4. RINEA

The Research and Innovation Network for Europe and Africa is a consortium of 13 partners; created in response to the call for proposals made at the 2014 EU-Africa Summit for cooperation in addressing STI priorities. RINEA seeks to complete project goals by structuring its operations into five complementary work packages; each with their own specific tasks in achieving the objectives set in the work program.

The project has set out to strengthen the quality and quantity of research and innovation between members of the consortium through: networking events aimed at the research and business communities, the elimination of obstacles to cooperation, optimising framework conditions and raising awareness about cooperation opportunities offered by H2020 and other EU-Africa programs.

RINEA wants to encourage transnational coordination of programmes and policies for international cooperation in STI in order to achieve: greater coherence, joint ownership and resource efficiency. The project attempts to do so by advancing the model created by ERAfrica for jointly-owned EU-Africa funding mechanisms, by facilitating the launch and management of calls for proposals on topics of mutual interest to the EU-Africa partnership (European Comission, 2015).

3.4.2. Research projects

The IRD office for Southern Africa has completed numerous scientific research projects with local academic partners. It is currently involved in coordinating with 4 research projects which cover research fields such as HIV prevention, marine and atmospheric sciences and land management.

3.4.2.1. TasP

Treatment as Prevention is a collaborative project between French Universities, Swiss and American Hospitals and a South African Research Organisation. It attempts to determine whether Anti-Retroviral (ARV) medication contribute in reducing HIV transmission at the individual and community level. The hypothesis is that testing all members of a community followed by the treatment of any individuals infected with HIV will prevent transmission and reduce the infection rate in this community.

The initiative was launched in 2012 in KwaZulu Natal, South Africa. The objective is to use cluster-randomised trials to assess the impact of ARV treatment on the incidence of additional infections in the general population of a particular region (IRD, 2016).

3.4.2.2. ICEMASA

Established in 2009, the International Centre for Education, Marine and Atmospheric Sciences over Africa is a joint venture between several laboratories in France and South Africa which focus on marine sciences over the Southern African coast and Southern Ocean through a multidisciplinary approach. ICEMASA collaborates closely in its work with the African Center for Climate and Earth Systems Science (ACCESS) which offers educational programmes, operational products, information on future global warming and coordinates research projects. ICEMASA consists of three components with specific aims:

- Research: creating knowledge along three axes; one related to climate and atmosphere research, the second related to ecosystem and fisheries research and the last one is an integrative axis where interdisciplinary research is developed to optimize the value of the scientific output and to provide a wider review of the effects of global change on marine ecosystems.
- Education: collaborating with ACCESS primarily to offer a joint South Africa-France post-graduate Master's programme which prepares students on a broad panel of multidisciplinary competencies and quantitative skills. ICEMSA also organises public outreach, conferences and workshops in order to involve and inform a wide range of stakeholders about global warming from an African perspective.
- Operational: developing a program together with the local private sector and ACCESS to answer end-user needs related to their professional and leisure activities that are linked to meteorological and marine conditions (ICEMASA, 2016).

3.4.2.3. Impact of land management on organic carbon outputs from soils

This research project collaboration between French and South African Universities started in 2013 attempts to understand the mechanisms behind the lower organic carbon – which is seen as crucial for plant growth – losses of no-tilled soils in KwaZulu Natal; where crop residues are exported from fields.

The hypothesis is that being able to answer this question will allow a better understanding of the mechanisms of organic matter stabilization in soils. This should enlighten the debate on the impact of land management on soil-organic carbon dynamics. This project has the medium-term goal of opening up research studies to the broader subject on carbon-loss mechanisms and to test forcing strategies on ecosystems through focussed agricultural management aimed at stimulating carbon storage in soils (IRD, 2016).

3.4.2.4. Upscaling understanding of water movement, land degradation and Carbon Cycle in support of effective Payment for Ecosystem services

This research project between the IRD, UMR LOCEAN and South African universities was conceived in 2013 to address the need for research-based assessments on important ecosystem services other than water conservation (for which Payment for Ecosystem Services has already been developed) such as soil conservation, carbon sequestration and food production.

This project seeks to improve land and water management through the development of research and capacity building activities focused on land degradation; together with the integration of different interactions between the pedosphere, biosphere and atmosphere. The project also seeks to test processes to rehabilitate degraded land in order to improve Payment for Ecosystem Services (IRD, 2016).

4. CONCEPTS FOR STI IN DEVELOPMENT

4.1. Dimensions of STI in development

Science, Technology and Innovation has allowed traditional and newly developed economies to continue their development and remain competitive relative to each other. The continuous investment in STI on their part has allowed them to create an infrastructure which acts as a global magnet for talent and creates wealth that funds future investment into the field.

Developing countries have the long term ability to create this kind of infrastructure which absorbs knowledge and applies scientific and technological expertise to the wide range of issues that mar the developing world. However, development needs more than just a high science and technology capacity in order to occur. Mutually dependent and complementary factors such as sound competition, fiscal and economic policies; accessible quality education and health services; together with good governance are essential in unlocking the potential offered by science and technology to development (Watson, et al., 2003).

4.1.1. Role of STI in development

Science, technology and innovation is inextricably linked to development through the field's historical performance in improving human livelihoods and productivity. Advances in STI can be construed as the single greatest global public good and are tantamount in solving the current and future challenges of economic development and poverty alleviation.

STI capacity is strategically vital to economic development and has been the highest in the developed countries which reaped the benefits of the industrial revolution; giving them a head start in terms of wealth creation and economic growth relative to the rest of the world. Recent studies have shown that the returns on investments in knowledge-intensive inputs have been consistently high and positive across the near entirety of industries observed. Certain developing countries such as China, India, Mexico, Brazil, Philippines, Thailand and Malaysia have combined their technological capacity with their comparative advantages to bolster their economic growth through high-tech manufacturing exports. However, maintaining an exclusive focus on high-tech industries while ignoring other sectors that are ripe for innovation could lead to a country incurring high costs without obtaining any of the benefits.

Poverty alleviation is also an area in which strong STI capacities have had tremendous impact and hold the highest potential to in successfully continuing the pursuit of poverty reduction in the future.

We can now examine some of the essential dimensions of human needs that have been impacted by STI and contributed towards poverty alleviation.

4.1.1.1. Agriculture

S&T played a vital role in improving global food security when the enhanced understanding of plant biology pre-empted the Green Revolution. This event led to improved seeds and cultivation techniques which drastically improved yields in many developing countries, thus lowering global food prices. A note must be made about Africa; due to the continent's low STI capacity relative to other developing areas, the benefits of the Green Revolution have not been entirely absorbed.

Food insecurity endures as a challenge to humankind as close to a ninth of the global population is currently food insecure (World Food Program, 2016) . Disciplines related to increasing agricultural productivity, reducing land degradation, improving the environmental resistance of crops, etc. will be crucial to dealing with the ever-growing demand for food. This second Green Revolution (International Rice Research Institute, 2014) has a strong genomic component mostly researched for profit in developed countries; this has raised a broad debate around the ethics of such enterprises.

4.1.1.2. Health

During the past 150 years, advances in the medical field through STI has increasingly improved global human health. On aggregate; life expectancy has increased, many scourge diseases have been exterminated and there has been a strong decline in routine health-related events. However, these aggregate measurements ignore the uneven distribution of global health issues, which are biased towards developing countries.

Poorer developing countries, particularly in Sub-Saharan Africa are still trapped within high fertility, high mortality cycles caused by a range of infectious and environment-related diseases. Many of these illnesses have been resolved in the developed world through STI diffusion yet continue to subsist due to factors which inhibit the uptake of health sector knowledge such as: incomplete individual knowledge about illnesses and health services; cultural and individual behaviour patterns and the lack of resources, institutions and infrastructure.

4.1.1.3. Water

Given the fact that about 1 in 10 humans do not have access to safe drinking, while 1 in 3 lack access to adequate sanitation; the World Economic Forum is justified in saying that the global water crisis poses the highest impact risk to society (Water.org, 2016). Access is only one facet of the problem, water pollution is another: it has severe negative developmental externalities on population health, biodiversity and food production. The combined necessity and scarcity of water makes the leveraging of STI output towards the sustainable management and universal provision of safe water to the global population; in order to avoid potential future crises related to the resource.

4.1.1.4. *Environment*

Environmental degradation is an almost immutable consequence of the economic development process and has an impact on the local, regional and global spheres. Issues such as land degradation, desertification and pollution in general have exacerbated effects in poorer, more rural communities that rely on their surrounding environment as a means of income. Developed countries are now moving towards more environmentally sustainable economic production methods and attempting to ensure that developing countries follow suit.

This is a problematic situation; as this type of production presents additional costs to developing country economies that rely heavily on their cost effectiveness as a way to attract investment and economic opportunity. On the other hand, there is an immediate need for the universal implementation of an adaption and mitigation strategy. The ability of STI to develop solutions that both sustainable and cost-effective is crucial in tackling the issues presented by environmental degradation.

4.1.2. Factors for successful STI

4.1.2.1. *Human capital*

The skills, abilities and knowledge obtained by a population through education is crucial to the success of its nation in using STI for development. In low income countries in particular, the role of human capital is particularly important in driving innovation within manufacturing SMEs which form the backbone of development (Voeton, 2015).

Human capital development for STI is initiated at primary and secondary education levels. Individuals should be provided with a broad basic science education which imparts them with scientific literacy. In order to convert this scientifically literate youth into productive actors in STI, policies and institutions that aim to stimulate interest for careers in the industry and provide a continuous renewal of skills and learning. Having created a broad and diverse labour force adapted to various levels of scientific levels of sophistication; a country needs to encourage the creation of knowledge and its application within its economy. This task is primarily driven by highly trained specialists in both the private and public sector, who must be adequately incentivised in order to hinder a brain-drain (OECD, 2012).

4.1.2.2. *Private sector knowledge demand*

Having a skilled human capital base is a necessary, but not sufficient condition for successful STI impacts on society. The knowledge supplied by these specialists requires a demand for it from the private sector in order to be applied economically. The private demand for knowledge is created through explicit and implicit policies. The former relates to reducing information barriers and costs of risk-taking in STI at the firm level. These types of policies involve strengthening both the informal industry-science cultures of information exchange and labour market linkages.

The implicit policies used create an environment supportive of STI investments and include macroeconomic stability, openness to FDI, credit availability and intellectual property rights – among many others.

These policies allow countries to maintain good investment climates and systematically facilitated and rewarded entrepreneurship, thus deepening their science and technology capabilities. Countries which have successfully pursued a policy of development through FDI have shifted their focus from the static advantage of low-cost factor and resource endowments to the more sustainable dynamic advantage proposed by flexible production and cost reduction.

4.1.2.3. *Public sector support for STI*

The STI field is highly intertwined with the provision of public goods which the private sector alone cannot supply in adequate quantities without the assistance of the public sector. The public sector should have a set of clearly delimitated roles in the STI system that must be continuously revised and reformulated in order to optimise policy concerning this system.

Governments should set national research priorities for their STI systems; while ensuring the diversity, decentralisation and balanced concentration and allocation of resources within the system. They are also responsible for creating, maintaining and evaluating the institutional framework that is necessary for a strong STI system. Lastly, the government is responsible for understanding and using STI output when making public and foreign policy decisions.

4.1.2.4. *Information & Communications Technologies*

Information access and diffusion is a key dynamic in promoting the creation and use of knowledge for innovation. This means that a robust national information and communication technologies infrastructure and institutional framework is necessary to use global knowledge efficiently.

The public sector has the responsibility to create a regulatory framework to enact the key conditions in reaping benefits from ICTs are the availability and affordability of the infrastructure and services related to it. ICTs can be used to reinforce the relations between the private sector, the public sector and the education system through an improved flow of information. An improvement in ICT capability can reduce transaction costs, increase the availability of economic opportunities in an economy and foster communities of knowledge.

4.1.2.5. *Globalisation & inclusive innovation*

The globalisation of production and innovation processes is an inevitable aspect of our modern economy. This means that a nation's success is highly dependent on its level of trade and FDI openness together with how well it supports its domestic innovative and productive capacity. Openness to trade has had numerous traditional benefits for developing economies which include: improved competition in domestic markets (leading to higher total factor productivity and innovation by domestic firms); technology and innovation transfers from foreign multinational corporations and economies of scale.

A more modern concept is that of the global value chain in which trade and production between countries are highly segmented within an industry. This has removed the need for countries to make the decision to support the creation of an entire industry and rather focus on specialising in particular segments of an industry. If a country is able to avoid modularity traps as its economy develops and moves towards higher value-add activities; it can benefit from global value chains substantially.

The governments of developing countries should however be aware of the power dynamics that global value chains and globalisation bring into play. The need to integrate smaller local producers into the value chains and using inclusive innovation is key to sustainable development.

Inclusive innovation can be used to reduce gaps in living standard by creating cheaper, simplified versions of goods (nutritional and health-related goods have the most impact) alongside redistributive policies and international aid. This type of innovation enables grassroots level entrepreneurship while also creating a market for businesses which makes it a potentially self-sustaining form of welfare improvement. In order for innovation to be inclusive at the national level, firms need to engage in innovation at a similar degree in order to prevent significant productivity gaps between them. If the bulk of STI investment are concentrated between a few firms, the aggregate transfer and dissemination of innovation cannot occur fully and its impact on development will be suboptimal.

4.2. Research for development

The human capacity to imagine solutions for the plethora of problems that our kind has faced since its inception is limitless. The emergence of intellectual property protection has allowed inventors and innovators to monetize their creativity. This formalised research yielded tremendous development gains during the Industrial Revolution for the countries involved in it. More recently, the Asian Tigers have developed through an intensification of their R&D sectors complementarily with export-led economic growth of high-technology manufacturing products.

In development circles, the question which dominates on the topic of research is on the type of research – basic of applied – that will create the highest positive spill-overs into a country. Basic and applied science play equally important roles in the development of a nation; they should both be supported relative to match the developmental needs of a country and its level of technological advancement. (OECD, 2012).

The conversion of this scientific knowledge into goods and services during the innovation process has been conceptualised in many ways. In 1911, the notable economist Joseph Schumpeter was the first to create a model describing a linear process of innovation: which subsequently drives development. This model has been refined to describe the multiple interaction between the stages of the innovation process and have led to the National Systems of Innovation (NSI) approach. The NSI framework provides an insight into the institutional linkages in the innovation process; this makes it an invaluable tool for the monitoring and evaluation of STI projects (Bernardes & Albuquerque, 2003).

4.2.1. Innovation models

4.2.1.1. Linear Innovation Model

The role of science within the innovation system was initially outlined by Vannevar Bush in 1945 in a report to the US president, Franklin D. Roosevelt. This paradigm gave rise to the Linear Model of innovation which states that: basic research creates the knowledge base of the economy to a point where it is refined through applied research; and the final research output is developed and commercialised into products or services. The model is described as linear because it assumes that spill-overs only occur from basic research to applied research. This model has been widely criticized for having untrue assumptions and a disconnection from empirical observations of the innovation system (Bentley, et al., 2015).

4.2.1.2. Chain-Linked Innovation Model

Kline and Rosenberg provided a more realistic description of the innovation process in 1986 with their Chain-Link Model of innovation. It describes innovation as a complex interdependent and heterogeneous process shaped by multidimensional feedbacks between technological and economic factors; which requires a contribution from both basic and applied sciences (Gulbrandsen, 2009).

4.2.1.3. *National Systems of Innovation Approach*

Due to the lack of technological convergence between countries, a new breed of institutional models has built on the Chain-Linked Model literature. The National Systems of Innovation approach to the innovation process explains how differences in: institutions involved in innovation, incentives to perform research and dissimilarities in firms (both locally and internationally) cause variances in the innovation performance of countries (Amon, 1979). This model sees private industrial R&D as the main driver behind innovation and the creation of new scientific areas, while basic research conducted in public research institutions is considered as a key complement to applied research.

This approach to the innovation process has been adopted by numerous developing nations as it provides an institutional framework which defines the division of labour between basic and applied sciences and thus allows a more efficient measurability and evaluation of STI projects. In return, this gives the domestic government enhanced oversight of its STI progress and allows it to make better policy-decisions. It also makes it easier for developing countries to receive funds, resources and partnerships from international donors involved in North-South cooperation (Baskaran & Muchie, 2008).

4.2.2. Basic research

4.2.2.1. *Definition of basic research*

Basic research is defined by the OECD as “experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view” (Amon, 1979).

4.2.2.2. *Role of basic research in innovation and economic development*

Basic research is primarily executed in universities and other public research institutions where in contrast to the private sector; there is less of a demand for the short-term applicability of the knowledge produced. Basic research makes an important impact on innovation by increasing the stock of available knowledge; which means that more knowledge can be commercialised innovatively. Basic research is helpful in importing and filtering foreign research, instrumentation and methodologies while improving the capabilities of domestic individuals completing PhDs and similar certifications. The training that these individuals receive allows them to be hired in innovative firms where they contribute to improving the absorptive capacity of the firm. On an aggregate level this raises the absorptive capacity of a country and thus allows for a more efficient use of knowledge towards economic goals (Salter & Martin, 2001).

4.2.3. Applied research

4.2.3.1. Definition of applied research

The OECD states that applied research is an "original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective". In the scope of this report, applied research can be understood as a combination of the OECD's definition of applied research and that of experimental development: "systematic work, drawing on knowledge gained from research and practical experience, that is directed to producing new materials, products and devices; to installing new processes, systems and services; or to improving substantially those already produced or installed" (Amon, 1979).

4.2.3.2. Role of applied research in innovation and economic development

Applied research is primarily conducted in for-profit organisations but has started becoming more prevalent in public universities seeking new sources of funding. Due to this type of research being oriented towards profits and the solving of tangible problems; it translates directly to goods and services which in turn contribute to GNP growth (COMSATS, 2007).

4.3. Elites and STI for development

A national elite can be defined as the top 3-5% of the most powerful members of a country. This small group hold positions of power in a vast range of public and private institutions and are seen as the main actors for shaping political and economic decisions in a society (Brannelly, et al., 2011).

The elites in developing countries often hold a sizeable piece of national income and all the power attached to such accumulated wealth. Political elites – globally – have used this concentrated power to control access to resources which can then be used as political patronage when distributed to a broad group of people in order to secure their backing. This kind of predatory elite is particularly prevalent in developing countries and one of the resources that lends itself to such practices is access to higher education.

Tertiary education is crucial in forming an involved and informed broader elite that can have an impact on the political process in their country. In terms of STI, a strong university system also allows a country to train a competent research community and attract foreign the talent required for a technological catch-up.

4.3.1. Education development in the South

Since the independence of former colonies in the 1960s, higher education has been seen as a factor which strongly contributes to development in those countries. This belief has pushed a large amount of aid donor support towards higher education and training. The education priorities for donors were shifted in 1985 after a journal article from the World Bank which saw that the private and social rates of return of primary education were much higher than those of higher education (Brannelly, et al., 2011). This resulted in a large multilateral drop in international funding towards higher education in the South, which was further compounded by the Millennium Development Goals focus on universal primary education. This neglect of higher education by multilateral organisations has hindered the integration of the South into the global STI community. However, there are countries that such as France, the UK, the USA, New Zealand and Austria that committed to improving the higher education sphere in the South through bilateral relations.

4.3.2. Role of higher education in development

Higher education provides society with technical and behavioural skills that are crucial in meeting the structural needs of the labour market; it also creates groups of individuals that have the capacity to be societally engaged. There is strong evidence which positively correlates higher education with better governance. Although it is a strong contributor, higher education is certainly not a sufficient pre-condition for good governance, as the improvement of governance is a complex multi-factor process. The elites play the role of strategic societal players who are responsible for creating a wider elite called the middle class – with the skills and capacity to hold the narrow elite accountable – to fill positions in all sectors of society.

Outlined below are areas in which higher education can be effective in creating development-oriented elites and improving governance indicators:

- Increasing access to higher education allows the formation of a middle class and the complementary network of professional associations to participate civically to a greater extent. This group can thus be in a position to shape institutions and hold their government in a manner which promotes economic growth and democracy.
- The nature and needs of the labour market evolves at the same pace as knowledge in the globalised economy. Higher education allows a country to meet the demand for technical and non-technical, cross-sectoral skills. Institutions involved in tertiary education have a recognised role in STI creation and transfers; which have positive spill-overs that are both economic and social.

4.3.3. The scientific diaspora in the case of African STI development

4.3.3.1. The African brain-drain

The global development community's focus away from higher education to basic education in the 1980s caused STI to deteriorate sharply in the majority of African nations. The drop in global financial support was combined with cuts in government spending on tertiary education and research institutes; which had seriously negative effects on the scientific infrastructure of these countries.

This resulted in a brain-drain where African academics left their academic institutes to pursue more lucrative and academically enhancing careers in international organisations, consultancies or even their own businesses (Gaillard & Gaillard, 2006). The outcome of this continuing exodus of skilled professionals from African academic institutions strongly inhibited Africa's capacity to be integrate the global scientific community and by extension its technology and innovation output has also suffered. The many countries on the continent is still trying to close a generation gap in the African academic labour force that opened in the 1990s due to the near absence of academic recruitment.

4.3.3.2. The diaspora model as a solution to the brain-drain

Since the early 2000s a discussion in political discourses and literature for utilising foreign-based African academics as a substitute for the issues faced by national scientific communities in Africa. The idea underpinning this model is to remotely engage African academics globally and valorise their expertise domestically. This solution is perceived by many African leaders to be a low-cost, self-sustaining solution to synergise the knowledge of their local and expatriate nationals through scientific cooperation networks and projects.

In order to successfully valorise the scientific diaspora community a country must: create and regularly update a database of skilled nationals abroad; mobilise them; reconnect these individuals with the domestic STI community; utilise their professional work and networks and facilitate interactions between them and the domestic scientific community through academic exchanges and common STI projects.

This ambitious approach to solving scientific capacity deficiencies requires a thorough amount of steps that require large: investments in effort, financial contribution and political will. It can be hard to align the diaspora community's objectives with those of their nation as those can diverge; as the universality of science will not necessarily always equate to the expatriate scientist's notion of national allegiance (Gaillard & Gaillard, 2003). Certain countries such as Egypt, Nigeria, Morocco and South Africa (with its South African Network of Skills Abroad framework) have been able to use the diaspora model efficiently. There are recommendations in the literature on ways to successfully apply the diaspora model to the general African context:

- Improve domestic science and technology systems to offer a minimum level of interaction between the diaspora and the local scientific community.
- Attempt to use the diaspora model at a regional level, where political and economic issues are shared.
- Strengthen domestic STI capacity, particularly ensuring a competent new generation of academics. This is crucial in terms of sustainable development as the diaspora community should not be seen as a substitute but as a complement to the local STI community.

4.4. Science Diplomacy

The term science diplomacy implies a nexus between multidisciplinary scientific activities and knowledge growth and the implementation of foreign policy through dialogue and negotiation in another country. International STI cooperation networks, projects and programmes between the North and the South are often science diplomacy initiatives; which were undertaken with aim of improving some aspect of a developing country's STI sector. The diplomatic corps facilitate these global networks which allow individuals and organisations access to the knowledge, institutions, funds and human capital that are key to a country's STI success (Gaillard, 1994). The Royal Society and the American Association for the Advancement of Science have defined science diplomacy in terms of three complementary dimensions (Ruffini, 2016).

4.4.1.1. Diplomacy for science

Countries promote their scientific community globally and create an environment that fosters international cooperation. Scientific attachés are charged with facilitating scientific mobility and providing support in negotiations to the representatives of their scientific community abroad. States cooperate in building, maintaining and bearing the costs of scientific infrastructure while yielding benefits therefrom through multinational research programs. The International Thermonuclear Experimental Reactor (ITER), the International Space Station (ISS) are the fruit of strong engagement by the leaders and diplomatic corps of all partner countries.

4.4.1.2. Science for diplomacy

Scientific relations are anecdotally able to withstand adverse diplomatic relations between countries; which helps in maintaining or even restoring bonds between two nations. The US and France have made use of this mechanism in the past: the former maintaining scientific and academic ties Iran since 2000 despite frosty diplomatic relations and the latter has financed archaeological expeditions in many war-torn countries; which has allowed France to keep contact with the scientific and civil circles in those countries.

4.4.1.3. Science in diplomacy

Many foreign policy decisions require scientific input before they can be made, particularly those concerning international negotiations on global challenges. Creating this link between policy makers and the scientific community requires a minimum level of scientific literacy from the former and an accessible formulation of scientific work by the latter. Maintaining and strengthening such links allows scientists and decision-makers alike to understand the dimensions of foreign policy and the role and capacity of science in that sphere. Policy on the global topics of food security, energy and climate change have benefited from science in diplomacy with the likes of the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Environment Program (UNEP) who were instrumental in the success of the COP21 climate conference (The Royal Society, 2010).

4.4.2. Brief history of science diplomacy

Science diplomacy itself is a concept created in the 20th century; but its roots can be traced back as far as the 18th century exploratory expeditions launched by European powers; which had both geopolitical and scientific objectives based on exploiting their colonial resources more efficiently.

The end of the Second World War signalled the start of formal science diplomacy as it served as the catalyst for a mass migration of scientists towards either the USA or the USSR due to their superior financial and infrastructural resources. This allowed these two countries to become the foremost producers of STI of the 20th century; which they used this to pursue their ideological competition. This was done by continuously drawing a ferociously patriotic scientific community from all corners of the globe through science diplomacy initiatives (Turekian & Neureiter, 2012).

The two countries used periodic scientific collaborations to relax Cold War tensions, particularly in the domain of their space programs. These ties became stronger towards the end of the of the Cold War, thus contributing towards nuclear non-proliferation agreements and ensuring that the collapse of the USSR did not lead to the dangerous illegal dissemination of its nuclear assets (Parker, 2016).

European science diplomacy emerged due to the massive exodus of their brightest minds towards either to the USA or the USSR. Despite having the ability to invest into scientific activities, European countries could not compete with the new superpowers through purely national programs. This prompted calls from scientists involved in the pioneering field nuclear physics for the cooperation of the European scientific community. The European Organisation for Nuclear Research (CERN) was created in 1954 by twelve countries in response to this call and has been an important component of the European scientific diplomacy since (Moedas, 2016).

In terms of modern North-South science diplomacy relations, Jacques Gaillard describes two phases of science diplomacy that follow the colonial era: the problem resolution phase which lasted between 1960 and 1970 and the capacity building phase that followed. This relationship has moved on from the transfers of science and technology and the creation and support of local capacities and specialised institutions that came purely from the North; to a more symbiotic and cooperative relation where the North and South see each other as partners (Gaillard, 2001). This topic of North-South cooperation is explored further in 4.4.6.

4.4.3. Trends in science diplomacy

Nations seeking to become and stay competitive in the global research and innovation community are faced with numerous challenges such as the lack of domestic valorisation of research, the lagging of certain scientific fields or the absence from a large part international science discourse. There are recent trends in science diplomacy that seek to address these issues; that are best explained by Carlos Moedas – the European Commissioner for Research, Science and Innovation – and his three O's (European Commsion, 2015).

4.4.3.1. Open Innovation

A term coined by Henry Chesbrough; he has given an updated definition of Open Innovation as: "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. (This paradigm) assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology" (Chesbrough, 2008). This kind of innovation accumulates the ideas and knowledge from a wide range of actors through the use of digitalisation, mass participation and collaboration to co-create products and solutions that deliver socio-economic value to their end users.

4.4.3.2. Open Science

Open Science was first described by Micheal Nielsen as: "the idea that scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process". Two recent global trends have led up to this concept: Open Source and Open Access. Open Source describes co-created software that is void of any proprietary restrictions which allow free access, use and modification. Open Access is the system of online peer-reviewed academic work with little or no copyright or licensing restrictions. This system is seen as a way to intensify and quicken knowledge creation by researchers through a framework which facilitates collaboration, communication and data analysis. The real life results of Open Science can be seen with the Human Genome Project in 1990 or more recently; the results from the sequencing of three viral genomes of Ebola victims which were released that same month. Pursuing the goal of Open Science will change the focus of scientists from publishing to knowledge sharing and hopes to make science better in its dimensions of: credibility, reliability, efficiency and responsiveness to socio-economic challenges.

4.4.3.3. Open to the World

Research and innovation is becoming an increasingly globalised field due to the emergence of new competitive international powers and the recent political will to focus more on global issues. Nations need to position itself in a manner which allows them to tap into exterior knowledge bases and attract global talent to carry out their research and innovation plans. In order to do so, countries must be "Open to the World" by interacting with global initiatives and organisations, optimising international synergies, contributing towards a framework – a Global Research Area – that allows more international cooperation, regular dialogue and engagement over global issues (European Commission, 2016).

4.4.4. French science diplomacy

France is the fifth biggest scientific power in the world and is represented in over 120 countries to promote its higher education and research (Ruffini, 2016). The country's approach to science diplomacy is executed through operational agencies in charge of promoting research with the South. It has its roots in colonial sciences which focussed on applied research, particularly in agriculture and tropical diseases.

France is a country that has maintained a comparatively large base of specialists within its institutes for development research (CIRAD, IRD, Overseas Pasteur Institutes) by prioritising the financing of programmes in which researchers from the North complete the majority of their careers as expatriates and work with or within institutions from the South. The focus of French science diplomacy – together with that of most former colonial powers – in order of importance are: agriculture, the environment and natural resource management; health and social sciences (Gaillard, 2001).

Modern French science diplomacy operates within the collaborative framework between the Ministry of Higher Education and Research and the Ministry of Foreign Affairs (Sénat, 2016). Together they defined the country's aims in the discipline under four points:

- Defending French science and technology interests, which are inextricably linked to national economic interests.
- Using scientific cooperation as a diplomatic tool with the view of: holding dialogues with closed-off countries, encouraging the creation of regional networks and promoting South-South cooperation.
- Using science in understanding and solving global issues.
- Promoting research for development as an integral part of development aid.

High level scientific cooperation has allowed France to promote an image of scientific and technological superiority which has attracted foreign talents that can further bolster this excellence. This yields positive externalities in supporting the international strategies and competitiveness of French companies (affirming the country's economic stance on the global stage), creating and strengthening relations with other nations and collaborating internationally in a more effective manner towards the resolution of global challenges through research (Directorate-General of Global Affairs, Development and Parnterships, 2013).

4.4.5. South African science diplomacy

South Africa is considered a historically strong country when it comes to science and technology research and cooperation. The apartheid period was certainly a hindrance to the field due to sanctions and boycotts; yet was unable to entirely destroy the high quality of research output in the country.

The democratic South Africa reformed the strong research structures left by the apartheid regime to promote developmental goals domestically and uses its current diplomacy agenda on three areas:

- Promoting international scientific cooperation
- Focussing international scientific cooperation towards political and developmental goals linked to foreign policy
- Contributing scientific content and diplomatic effort to international relations challenges (Pandor, 2012).

4.4.5.1. Pre-1994 scientific collaboration

South Africa was the recipient of scientific personnel and activities from its colonial governments since the late 17th century. This early scientific flow was crucial in establishing the disciplines and institutions which would shape science and proactive scientific collaboration in the country for years to come (Sooryamoorthy, 2013).

The infamous system of apartheid which stemmed from post-colonial thought; drew extreme ire from the international community for its politics of discrimination and racial preference. The resulting backlash in the form of an academic boycott slowed the growth of science in South Africa. However, scientific contacts were maintained throughout apartheid with Europe and the US; contributing to advancing South Africa's nuclear program to the point where the regime was in possession of domestically enriched and manufactured atomic weapons.

The apartheid administration thus longed for a national identity and independence for South African scientific output. It steadfastly pursued domestic investments and efforts in science and technology, which meant that the international boycott could not stop the country's scientific advancement; due to its already strong science framework. Some notable results that emerged in these times are: the first heart transplant performed in Cape Town by Christiaan Barnard in 1967 and converting coal into oil at an industrial level by SASOL; in response to the scarcity of oil due to economic embargoes. Leading projects was performed with US organisations such as NASA, the National Institute of Health, the Atomic Energy Commission and the California Institute of Technology's Jet Propulsion Laboratory (Sooryamoorthy, 2009).

4.4.5.2. Post-1994 science diplomacy

In 1996, the newly elected democratic government published a white paper that emphasised instrumental role of science and technology in the development for South Africa. Contrary to the previous regime, the government saw this field as one that contributes beyond economic growth and military advances but can also assist in competitiveness, social development and poverty alleviation.

Since 2002, South Africa possesses a Department of Science of Technology (DST) dedicated to coordinate national research and innovation activities; including the country's international scientific and technological cooperation. In order to achieve the national objectives of science diplomacy, the DST works closely with the Department of Trade and Industry, the Department of Environmental Affairs and the Department of International Relations and Cooperation. There are also a number of national science councils and public research and technology organisations such as the National Research Foundation that coordinate with government departments in brokering and implementing international science and technology cooperation agreements.

South Africa pursues international scientific cooperation as both a goal and as a mechanism to satisfy strategic national and foreign policy aims. National research and innovation programs require international investments and cooperation in order to address the developmental issues faced by South Africa. The country's use of science diplomacy in a bilateral framework is important in strengthening political and economic ties with international partners. Multilaterally, it is used as a platform with which to leverage scientific cooperation and to build trust and relationships with strategic partners in reaching a consensus on issues of mutual interest.

South Africa's science diplomacy agenda is also strongly focussed on South-South development. It is in the privileged position in receiving support, science and technology development aid from developed partners; while also being able to dispense it to other developing economies. South Africa has been a catalyst in the support of numerous African initiatives such as the African Network for Drugs and Diagnostics Innovation and the New Partnership for Africa's Development which yielded the African Laser Centre in Pretoria and the African Institute for Mathematical Sciences in Cape Town. South Africa's successful cooperation in the EU's Framework programmes for Research and Technological Development and its current involvement in the Horizon 2020 programme has allowed to make it a voice for the South in the global science and technology debate.

4.4.6. North-South cooperation for development

It is impossible for any one nation to maintain a complete independence of its STI capability if it seeks to develop in a sustainable manner. The costs of acquiring knowledge and STI capacity are high for developing countries that have pressing socio-economic issues which are inhibiting their development. North-South scientific collaboration allows developing nations to be in a position where they can gain rapidly from the North's wealth in knowledge and experience and participate in the global scientific community (UNESCO, 1999).

In the past, scientific cooperation distinguished specific roles for the North and the South. The former would act as a facilitator and supporter of the latter in all activities that were linked to capacity building. North-South STI programmes might be qualified as "capacity-building", but these are not necessarily about building institutions and STI capabilities from scratch. These programmes are centred around using the current capacities of a country; and creating a framework which enables the local institutions and organisations to improve a narrow and mutually beneficial set of capacities in specific disciplines (COMSATS, 2007).

The power dynamic between the North and the South has evolved from being a very one-sided affair towards equitable partnership structures for STI cooperation. Partnerships are often complicated due to the structural inequalities that exist between participating countries and institutions (Jentsch & Pilley, 2003). This asymmetry in partnerships is also due to diverging research priorities between the North and South; and the fact that not enough emphasis is given to the South's influence on the North's STI capacities. Lastly, there is often an unfair division of labour between North-South partners: where the North is included in from the planning of the programme proposal all the way through to the dissemination of results while the South is only included in the implementation stage.

When discussing North-South cooperation, one must make a side note on South-South cooperation: it gives scientists from developing countries the opportunity to identify their own problems and design solutions for them. This also creates a stronger identity for the South's scientific capacity, which it can use to negotiate with Northern partners when creating new projects

Not every North-South STI cooperative project is flawed, as the issues that have been mentioned have been duly noted by the international aid and scientific community. Guidelines for research in partnership between the developed and developing countries were drawn up by the Swiss Commission for Research Partnership with Developing Countries. Jacques Gaillard (1994) refined these guidelines into the Charter for North-South Partners[1]. This document has helped guided countries and organisations involved in North-South scientific collaboration towards more equitable partnerships. If cooperation is done right, it allows scientific networks to harness the diverse intellect (Gaillard, 2001) of a wide variety of individuals and organisations towards finding original solutions to common objectives; which have positive spill-overs for both the North and the South (Binka, 2005).

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[1] Appendix 1

5. INDICATORS OF RESEARCH & INNOVATION IN DEVELOPMENT

An essential part of any decision-making process is being able to measure the impact of a policy in different dimensions – individual, national, institutional. The bulk of the literature on STI indicators is contained within the: Oslo, Frascati and Patent Statistics manuals. The Oslo Manual is the global standard in terms of collecting and analysing innovation data at the firm level. The Frascati Manual is used to measure the resources devoted to the STI sector, while the Patent Statistics Manual devotes its focus to the factor which influence the best use of patent statistics. Many of these manuals were formulated to study the R&D in developed economies and have been subsequently adapted to be of use to developing countries. Emerging economies also collaborated to produce their own, more adapated STI indicator manuals, one such initiative is African Science, Technology and Innovation Indicators (ASTII) Indicator Manuals. Once completed, this project has the potential to bolster the African STI development effort; which is currently being led by South Africa, Egypt, Nigeria and Kenya. The STI performance of these countries is compared according to various indicators later in the report.

Purely scientific activities can be measured at the individual, group and firm levels by using bibliometric indicators to quantify scientific production in terms of volume, quality and knowledge linkages. There are numerous types of bibliometric indicators which can be determined from online scientific knowledge databases such as the ISI Web of Knowledge or Google Scholar. A simple measure for technologic production comes in the form of patent indicators, which are very similar to bibliometric indicators yet not as advanced as a field of research itself. The measurement of the STI sector as a whole can also be viewed through the lens of institutional indicators such as statistics related to R&D expenditure and various indices.

5.1. Bibliometric indicators

Bibliometric indicators attempt to assess the quantity and impact of scientific output as a measurable proxy for the complete stock of scientific research. These indicators are linked to a formula combining the count scientific publications and the citations derived from them. These measures are widely used in the research and development field by both public and private institutions for the purposes of: programme evaluation, gauging the levels of scientific capacity and measure scientific cooperation networks in the global scientific community.

The relevance of these indicators in academia is seen as a competitive measure necessary to drive the production of quality scientific output. Papers that are considered to have an impact are those which are cited the most often in other academic work. Bibliometrics are not considered a completely reliable proxy; as the publications with the best impact factors are usually based within more classical scientific disciplines, have a broad international scope and are predominantly written in English. This can lead to interpretation issues of these indicators; which tend to affect developing countries disproportionately. This linguistic bias excludes a large portion of the pool of scientific talent in developing countries who often have difficulties with writing their paper in English or lack access to a translator and tend to focus on research which focusses on finding solutions to local problems.

Bibliometric indicators are also prone to excluding a large part of R&D output as their disciplinary focus is narrow and they also underestimate the role of applied science and technological development in the R&D process (UIS, 2005).

The political utility derived from the use of these indicators in decision-making on matters such as funding, project approvals or appointments; has spawned a wide range of complex indicators and indices to improve their accuracy. Performance indicators such as the h-index and impact factor have been particularly influential and the g-index, average-weighted citation ratio (ACWR), Crown Indicator, and Eigenfactor score all attempt to improve on the h-index and IF formulae.[2] Bibliometric indicators can be placed in 3 categories: quantity indicators, performance indicators and structural indicators (Durieux & Gevenois, 2010).

5.1.1. Quantity indicators

Quantity indicators measure the research productivity of a particular individual or group of researchers. The simplest quantity indicator is the result of a count of a researcher's publications, where quality is excluded from the metric and can only be gauged by looking at the methodology employed. This method can be improved by counting the number of publications in highly-ranked academic journals.

5.1.2. Performance indicators

Performance indicators allow the assessment of individual researchers, groups of researchers or academic journals in terms of their quality. This can be used to determine the impact of a specific publication on the scientific community. These metrics are generally based on equating the amount of citations received by an article or a journal, to its performance in terms of quality and scientific impact.

5.1.2.1. Individual or research group performance indicators

- **H-index:** was developed by Hirsch as a measure of an individual researcher's scientific impact; where the higher the h-index, the higher the impact. This metric works simply; where an h-index of 5 means that the across all publications by the researcher, 5 of them have received a minimum of 5 citations each. Furthermore, Hirsch has developed interpretable thresholds of an h-index for a researcher's activities over a 20-year period: 20 can be seen as "successful", 40 as "outstanding" and 60 as a "truly unique individual" (Hirsch, 2005).
  This method is the most commonly used indicator for individual researchers as it is calculated for free on Google Scholar or on the subscription-based Web of Science. The h-index takes into account all the publications on which an author has their name regardless of their position on the author list. It is also insensitive to both frequently cited articles and rarely cited publications; which should incentivise researchers to produce a continuous, above-average impact stream of scientific output instead of sparse high-impact articles.

[2] Appendix 2

Like any measure the h-index has disadvantages:

1. Its calculation can be erroneous due to the misspelling or homonymy of names.
2. It is extremely sensitive to the characteristics of different scientific fields and is thus an unreliable cross-field measure of scientific performance.
3. The h-index increases in value with time and thus favours researchers with longer careers, regardless of the quality of their publications during their career

- **Crown Indicator:** measures the scientific impact of individual researchers and research groups. This indicator was developed by the Centre for Science and Technologies Studies at Leiden University in the Netherlands. It is calculated by taking the average number of citations received and dividing it by the average number of citations that are expected – in a given year, type of publication and scientific field. It is represented as a decimal number with a normal distribution and an average of 1, where as an example: 1.1 would signify that the researcher or group is cited 10% more than the world average.

  This indicator overcomes the biases suffered by the IF – due to its sensitivity to scientific field characteristics and journal types – by controlling for citation rates in terms of the field, year and publication type. The crown indicator has its own limitations:

  1. It assigns publications to research fields by using the Thomson Reuters subject categories for journals, which does not account for articles from one field being published in journals categorised in a different field. This particular problem could be solved by categorising publication based on their topic rather than on that of the journal it is published in.
  2. The crown indicator can only be used to compare research groups reliably if they are of similar sizes, because the size of a group will influence its scientific productivity.

5.1.2.2. Journal performance indicators

- **Journal Impact Factor (IF):** the most widely used indicator across scientific fields was proposed by Eugene Garfield in 1955 and later conceptualised with Irving H. Sher in the early 1960s. The IF of a journal is calculated biennially by looking at the number of citations received by articles published in the journal divided by the number of articles in the journal that had the potential to be cited. The journal IF has numerous flaws which must be taken into account if the metrics it offers are to be understood fully:

  1. A higher IF does not reflect the quality of each article published in the journal, but rather suggests that the journal itself has a greater impact. This is due to the majority of citations generated coming from a small portion of high quality articles published in many top journal.

2. Specialised journals usually have a lower IF than multidisciplinary journals because the latter has a wider readership which results in a higher citation count. This gives rise to a paradoxical situation for researchers looking to publish their work: they can publish in a prestigious journal with a high IF and a wide audience; or they can publish in a specialised journal with a lower IF, but a much more appropriate and targeted audience.
3. The IF does not account for the differences in research intensity across various scientific fields and is thus useless in comparing journals from different fields. These differences are caused by differing: popularity of fields (the amount of researchers in that field), citation habits (the average number of citations per article) and citation dynamics (the period between the publication of the article and when its citations have peaked).
4. Certain types of articles such as technical reports and reviews are cited more often than original research articles and case reports. This means that journals are incentivised to publish more technical reports and reviews instead of other types of articles to maintain or improve their IF score.
5. The IF of journals is vulnerable to being manipulated by editors seeking a higher IF. This can be done by promoting review articles and technical reports, reducing the percentage of manuscripts that are approved for publication and by incentivising authors to cite publication from the journal.

- **5-year journal IF:** is similar to the original IF but instead of a 2-year citation period, it makes use of a 5-year citation period. It is useful in evaluating theoretical field that have a more constant type of literature.
- **Immediacy Index:** takes into account the average number of times a publication from a given journal and year has been cited that very year. This metric is significant in gauging the importance of published academic work, particularly in emerging scientific fields. This indicator is often skewed due to its yearly calculation, which causes it to include more cited articles that were published earlier in the year than later.
- **Cited half-life:** is the period of time between the publication of a cited article and the publication of articles which cite it. This indicator does not reflect the scientific value of a journal but can provide insight into editorial policies or scientific fields, where a short cited half-life is indicative of: an editorial policy pushing for the dissemination of current knowledge or a research field that is growing quickly.
- **Journal-to-field impact score:** this indicator was developed as an alternative to the IF by the Centre for Science and Technologies Studies at Leiden University. This measure is calculated by comparing the average number of cited articles in a given journal with that of other journals in the same journal subject category. The journal-to-field impact score corrects the misgivings of the IF score in terms of comparability between journals of differing research fields.

- **Eigenfactor:** is a newly proposed indicator which improves on the IF because it accounts for the quality of the citing journals by calculating the weight of their citations according to their impact on science. This indicator treats scientific works as a network of publications that are connected to each other via citations. The Eigenfactor determines the place of a particular journal in this network through an algorithm which estimates the time spent or views by a researcher on a specific journal; the more each journal is visited by the researcher, the more impact it is deemed to have on the scientific community.

5.1.3. Structural indicators

Structural indicators quantify the connections between fields of research, academics and publications in a scientific network. These measure whether the research is basic or applied, in which fields the article is published, in which fields it is cited and what the cognitive structure of a particular field looks like in terms of author characteristics.

5.1.4. Sources of data

Scientific performance indicators are calculated with data obtained from citation indexes. There are numerous bibliographic databases – each with their own strengths and weaknesses – that allow a large amount of scientific output to be organised and navigated efficiently (Jones, et al., 2011). This report will look at two major bibliographic databases: the Institute for Science Information (ISI) Web of Knowledge and Google Scholar. Both these resources have their limitations and should thus be used complementarily.

5.1.4.1. ISI Web of Knowledge

Created by the ISI in 1963, the Science Citation Index is the most commonly used scientific index. It is now owned by Thomson Reuters who have been maintaining an extensive subscription-based online database called the ISI Web of Knowledge; which provides access to research resources and tools such as the Web of Science and the SCI Journal Citation Reports.

The Web of Science offers access to six multidisciplinary databases which cover more than 8000 scientific journals in a wide variety of scientific fields. The SCI Journal Citation Reports provide subscribers with analytical and statistical information on citation data in the form of quantity and performance indicators. This resource has its faults however:

1. Performance indicators are only calculated for journals that are included in the Web of Knowledge database and the citations received from journals that are not included are also excluded from the calculation.
2. Wrongly cited references have a strong impact on the resulting indicators, as the calculation and matching processes between citing and cited publications is completely automatic.

5.1.4.2. Google Scholar

Google Scholar is a free, web-based database created by Google to compete with the ISI Web of Knowledge in terms of citation analysis and bibliometric indicators; by covering a wider range of academic materials. Google Scholar has limitations too:

1. Its reporting of publications before the 1990s is poor and it is not consistent across scientific fields.
2. It includes gray literature – documents produced for a limited audience without the normal review and editorial processes – in its citation counts.
3. It duplicates citations, which makes its citation references unreliable.

5.2. Patent indicators

A patent – on databases such as NBER, Patstat, IIP, USPTO and EPO – can be used as a measure of technological output at the firm, industry and national level. These indicators offer cruder measures than bibliometrics that measure scientific output; yet remain particularly useful when they are citation-weighed and correlated with variables such as: knowledge asset value, R&D expenditure, profits, legal proceedings, etc. These analyses offer great insight over time about the impacts of STI policies and allow a partial measurement of the cross-border impact of knowledge assets

Like all indicators, patent counts suffer from instabilities in their measurement. They fall prey to biases which result from: the differing costs and benefits across countries; relative differences between technologies and sectors in intellectual property protection; and the fact that firms do not have homogenous patenting strategies. Furthermore, the ICT dissemination of patent data is not as widespread as that of scientific publications; the online data from major patent offices are not optimised for statistical analysis or rapid searches (Hall, 1999).

5.3. Institutional indicators

5.3.1. Gross Domestic Expenditure on R&D (GERD)

GERD is the main indicator contained within the Frascati Manual and sums up the sectoral – business, university, government and non-profit – R&D spending in the economy. When combined with Gross National Product (GNP), it is the preferred indicator of multilateral organisations and governments alike for setting STI goals and measuring R&D on a national scale to better determine national R&D budgets. This indicator has its flaws however:

- Many countries will overspend on STI for prestige.
- It does not give an insight into the causal relationship between GNP and GERD.
- GERD and the analyses based around it do not account for the diversity of sectors or countries (Godin, 2003).

5.3.2. Composite indicators

Composite indicators are a mathematical aggregation of sub-indicators that have no common unit of measurement and weighting between them. They allow policy-makers to have a summarised version of multi-dimensional factors and to communicate complex sub-indicators in a way that the general public can understand. These composite indicators must be well-constructed to prevent them from providing misleading and simplistic policy insight (European Commission, 2016). There are a number of composite indicators – in the form of indexes – used to measure the dimensions of the STI sector at a national level.

5.3.2.1. Industrial-cum-Technological Advance (ITA)

ITA is an index developed by the United Nations Industrial Development Organization to assess the role and interplay between industrial and technological development in a country. This index ranges from the lowest score of 0 to 1 and combines 3 dimensions: the level industrial activity, Industrial Advancement Index (IAI) and Technological Advancement Index (TAI). Each of these dimensions are based on 2 indicators each:

- Level of Industrial activity: industrial output per capita, manufactured exports per capita.
- IAI: share of industry in total production, share of industry in total exports.
- TAI: share of medium-or-high technology goods in industrial production, share of medium-or-high technology goods in manufactured exports (UNIDO, 2005).

5.3.2.2. Global Competitiveness Index (GCI)

Contained within the Global Competitiveness Report, GCI is the World Economic Forum method of assessing and ranking countries according to their competitiveness: “the set of institutions, policies, and factors that determine the level of productivity of an economy” (World Economic Forum, 2015). It aggregates 114 indicators into 12 pillars which fall under 3 sub-indices linked to stages of economic development:

- Basic requirements sub-index: institutions, infrastructure, macroeconomic environment, health and primary education.
- Efficiency enhancers sub-index: higher education and training, goods market efficiency, labour market efficiency, financial market development, technological readiness, market size.
- Innovation and sophistication sub-index: business sophistication, innovation.

5.3.2.3. Networked Readiness Index (NRI)

NRI is an index compiled by the World Economic Forum as part of its Global Information Technology Report to assess the capacity which countries have in utilising ICTs for inclusive growth, higher competitiveness and population well-being. This index is based on the networked readiness framework developed by the World Economic Forum and consists of 53 individual indicators divided across 4 sub-indices:

- Environment sub-index: political and regulatory environment, business and innovation environment.
- Readiness sub-index: infrastructure, affordability, skills.
- Usage sub-index: individual usage, business usage, government usage.
- Impact sub-index: economic impacts, social impacts (World Economic Forum, 2015).

5.3.2.4. Global Innovation Index (GII)

The GII is the leading reference for capturing the multiple dimensions of global innovation. This co-published report from the Cornell University, INSEAD and the WIPO ranks countries according to their innovation capabilities and results. The GII, consists of 82 individual indicators spread across 7 pillars upon which are seen as enablers of innovative activities, who are then aggregated into 2 sub-indices:

- Innovation Input sub-index:
    - Institutions: political environment, regulatory environment, business environment.
    - Human capital & research: education, tertiary education, research & development.
    - Infrastructure: ICTs, general infrastructure, ecological sustainability.
    - Market sophistication: credit, investment, trade competition & market scale.
    - Business sophistication: knowledge workers, innovation linkages, knowledge absorption.
- Innovation Output sub-index:
    - Knowledge and technology outputs: knowledge creation, knowledge creation, knowledge diffusion.
    - Creative outputs: intangible assets, creative goods and services, online creativity (Cornell University; INSEAD; WIPO, 2016).

5.4. Brief comparison of STI for leading African states

The developmental and economic gap between the North and Africa is linked the differences in STI between them. In order to be sustainable, a STI sector needs to keep up with the global knowledge industry and have locally set agendas in order to contribute to the development of emerging economies. Strengthening Africa's STI capacity is a necessary condition for a sustainable development that both alleviates poverty and enables a technological catch-up.

The four countries most involved in African STI are Egypt, Kenya, Nigeria and South Africa. These countries have a shared history of colonialism, yet have developed in very different manners. This is also the case of their STI sectors in terms of structure, planning, networks and research themes. A number of STI indicators for each nation is available for consultation in Appendix 3 to assess their level of STI capacity, together with this short summary of the figures.

5.4.1. Statistics summary

South Africa and Egypt are clear leaders in this field on the African continent with the highest S&T output with a similar amount of patent applications and scientific publications. Egypt has the largest human capital base for R&D on the continent; employing over 1000 researcher and technicians per million people. Kenya has an extremely technician-intensive STI sector for an African economy, partly due to the policies related to its Vision 2030 plan.

With an H-index of 320 compared to Egypt's score of 184, South Africa's scientific publications are of a higher quality than the other countries being compared. South Africa and Nigeria are also the top producers of process knowledge in terms of trademark applications. Comparing these four countries only allows us to capture a small portion of the picture however. The majority of African economies have STI indicators that are much weaker than those in Appendix 3 and the top 4 African nations discussed still lag behind many other emerging economies.[3]

5.4.2. Country STI profiles

5.4.2.1. Egypt

The Egyptian STI system is governed by the Ministry of Scientific Research (MSR) which manages the main STI instruments: the Research, Development and Innovation Programme and the Science and Technology Development Fund. The High Council for Science and Technology is the highest consultative authority for STI policy setting and orientation. In tandem with the MSR, numerous other ministries implement plans to promote technology and innovation development in the both the public and private sector.

The government has outlined two frameworks through the MSR and the Ministry of Higher Education to guide STI policy in Egypt from 2007 to 2016: the Decade for Science and Technology and the Developing Scientific Research Plan. The country has prioritised ICT, biotechnology, nanotechnology, food, health and water management for STI development (Zentrum für Soziale Innovation , 2013).

[3] Appendx 3

5.4.2.2. Kenya

Kenya's STI system is managed by the Ministry of Science and Technology; whose stated mission is to apply STI to all sectors and processes of the economy to ensure that its population will benefit STI in achieving the national long-term development strategy called Vision 2030.

Kenya has prioritised specific sectors that its government sees as significant to achieving its economic growth and development targets: agriculture, the health system, trade and industry, human capital, physical infrastructure, energy, environment management and ICT. The Ministry of Science and Technology has specified that it will pursue its strategic STI objectives by: reforming its institutions related to the Kenyan National Innovation System, mobilising strategic resources for STI, improving knowledge and technology governance and address cross-cutting issues within STI networks (Republic of Kenya, 2008).

5.4.2.3. Nigeria

The Federal Ministry of Science and Technology (FMST) is responsible for planning and implementing Nigeria's STI policy since 1986. The FMST works in tandem with the National Council on Science, Technology and Innovation, the National Centre for Technology Management, amongst many other governmental and academic institutions.

The country's current STI policy was created in 2012 to better integrate economic planning with STI in order to reach the goals set out by the Nigerian government in its "National Vision 20:2020 Economic Transformation Blueprint". The current policy aims to promote a citizen-centred economic transformation driven by private sector engagement with STI.

While stressing the need for a multi-disciplinary approach to STI activities, this policy maintains a sectoral focus on: agriculture, water resources, biotechnology, health, energy, environmental science, mines and mineral development, ICT, space research, nanotechnologies, defence and national security, transport, tourism and urban development. (Zentrum für Soziale Innovation , 2013)

5.4.2.4. South Africa

South Africa's main agent for STI policy is the Department of Science and Technology (DST); with funding being primarily dispensed by the National Research Foundation and the Technology and Innovation Agency. South Africa has numerous ministerial departments with significant research responsibilities that work in close collaboration with the DST.

STI policy in South Africa is outlined in the National Research and Development Strategy and the Ten-Year Innovation Plan. The latter guides the country's transition to a knowledge-based economy by: promoting multi-disciplinary approaches from its research community, improving South Africa's national innovation system, increasing investments into STI and assisting the creation of technology intensive sectors while decreasing the reliance on foreign technology. The STI strategy focusses on the following sectors: biotechnology, pharmaceuticals, space science and technology, energy security, global change science focussing on climate change, human and social sciences, palaeontological sciences, indigenous knowledge systems, ICT and nanotechnology (Zentrum für Soziale Innovation, 2013).

5. QUESTIONNAIRE

The time period during which my internship took place was not favourable to disseminating the questionnaire[4] I have created to supplement my bibliographic research on the subject of the role of research and innovation in development. Pending a confirmation and guidance from my internship supervisor, this section of the research report will be continued after the formal end to my internship as a point of personal interest.

6. CONCLUSION

STI is clearly a driving force behind the development of both the North and the South. In order for the South to pursue a sustainable technological catch-up; emerging economies need to have measurable STI plans and strategies that fully utilise the resources of the global STI community. This can be done by leveraging science diplomacy to allow the South to integrate the global STI networks and policy decisions; while correctly identifying and funding domestic STI initiatives with significant returns on investment.

This internship report has provided an introductory insight into the role and importance of STI on the development of economies from both the North and South. It has described the mission, structure, research and partnership activities of the Institut de Recherche pour le Développement – a major actor in the global STI community – in general and with a specific focus on Southern Africa. This report explored important concepts relating to STI in development such as the most effective research types, the roles of elites in coupling STI with development policy and the relevance of science diplomacy. The topic of STI indicators was also investigated greatly through the lens of bibliometric, patent indicators and institutional indicators. Appendix 4 contains a questionnaire meant to supplement the bibliographic research which makes up this report. The time period of the internship was not favourable to conducting questionnaire-based research and this undertaking will be left to the discretion of my supervisor. The information that could be sourced from this questionnaire is likely to provide a personal insight into the perceptions and realities which exists in the global STI community.

[4] Appendix 4

7. REFERENCES

Sooryamoorthy, R., 2013. *Scientific collaboration in South Africa,* Durban: South African Journal of Science.

Turekian, V. C. & Neureiter, N. P., 2012. *Science and Diplomacy: The Past as Prologue,* s.l.: AAAS Center for Science Diplomacy.

Amon, C. A., 1979. *Basic Reesearch, Innovation and Economic Growth,* s.l.: s.n.

Baskaran, A. & Muchie, M., 2008. *The Impact of the National Innovation Systems on the Flow and Benefits of Foreign Direct Investment to National Economies,* s.l.: s.n.

Bentley, P. J., Gulbrandsen, M. & Kyvik, S., 2015. *The relationship between basic and applied research in universities,* s.l.: Higher Education.

Bernardes, A. T. & Albuquerque, . E. d. M. e., 2003. Cross-over, thresholds, and interactions between science and technology: lessons for less-developed countries. *Research Policy,* Issue 5, pp. 865-885.

Binka, F., 2005. *North–South research collaborations: a move towards a true partnership?,* s.l.: Tropical Medicine & International Health.

Brannelly, L., Lewis, L. & Ndaruhutse, S., 2011. *Higher Education and the Formation of Developmental Elites: A literature review and preliminary date analysis,* s.l.: DLP.

CAAST-Net Plus, 2016. *Aims and Results.* [Online]
Available at: https://caast-net-plus.org/about/goals
[Accessed 21 August 2016].

Chesbrough, H., 2008. *Open Innovation.* [Online]
Available at: http://openinnovation.net/about-2/open-innovation-definition/
[Accessed 21 August 2016].

COMSATS, 2007. *Basic or Applied Research: Dilemma of Developing Countries,* Islamabad: COMSATS.

Cornell University; INSEAD; WIPO, 2016. *The Global Innovation Index 2016: Winning with Global Innovation,* Geneva: Cornell University; INSEAD; WIPO.

Directorate-General of Global Affairs, Development and Parnterships, 2013. *Science Diplomacy for Frabce,* Paris: Ministere des Affaires Etrangeres.

Durieux, V. & Gevenois, P. A., 2010. Bibliometric Indicators: Quality Measurements of Scientific Publication. *Radiology,* 255(2).

ERAfrica, 2016. *about ERAfrica.* [Online]
Available at: http://www.erafrica.eu/en/159.php
[Accessed 21 August 2016].

European Comission, 2015. *Research and Innovation Support for Europe and Africa.* [Online]
Available at: http://cordis.europa.eu/project/rcn/194395_en.html
[Accessed 21 August 2016].

European Comission, 2016. *Strengthening Technology, Research and Innovation Cooperation between Europe and South Africa 2020.* [Online]

Available at: http://cordis.europa.eu/project/rcn/204153_en.html
[Accessed 21 August 2016].

European Commission, 2016. *Open innovation, open science, open to the world.* Brussels: European Commission.

European Commission, 2016. *What is a composite indicator.* [Online]
Available at: https://composite-indicators.jrc.ec.europa.eu/?q=content/what-composite-indicator
[Accessed 21 August 2016].

European Commssion, 2015. *Open Innovation, Open Science, Open to the World.* [Online]
Available at: http://europa.eu/rapid/press-release_SPEECH-15-5243_en.htm
[Accessed 21 August 2016].

Froghi, S. et al., 2012. Indicator for Research Performance Evaluation: An Overview. *BJU International,* 109(3), pp. 321-324.

Gaillard, J., 2001. Diversité des politiques nationales de coopération scientifique. In: M. Dron & M. d. Lattre-Guasquet, eds. *Politique d'aide et de recherche agricole : bilan et perspectives.* Paris: INRA, pp. 113-151.

Gaillard, J. F., 1994. *North-South Research Partnership: Is Collaboration Possible between Unequal Partners?,* Paris: ORSTOM.

Gaillard, J. F., 2001. *North-South scientific cooperation : a view from the North,* s.l.: IRD.

Gaillard, J. & Gaillard, A. M., 2003. *Can the scientific diaspora save African science?,* s.l.: SciDevNet.

Gaillard, J. & Gaillard, A. M., 2006. Fuite des cerveaux, circulation des compétences et développement en Afrique : un défi global. In: P. Marc, ed. *Défis du développement en Afrique subsaharienne : l'éducation en jeu.* Nogent-sur-Marne: CEPED, pp. 37-65.

Godin, B., 2003. *The Most Cherished Indicator: Gross Domestic Expenditures on R&D (GERD),* Montreal: Canadian Science and Innovation Indicators Consortium (CSIIC).

Gulbrandsen, M., 2009. *The Role of Basic Research in Innovation,* s.l.: ResearchGate.

Hall, B. H., 1999. *Using patent data as indicators,* s.l.: OECD.

Hirsch, J. E., 2005. An index to quantify an individual's scientifici research output. *Proceedings of the National Academy of Sciences of the United States of America,* 102(46), pp. 16569-16572.

ICEMASA, 2016. *ICEMASA.* [Online]
Available at: https://www.icemasa.org/
[Accessed 21 August 2016].

International Rice Research Institute, 2014. *The second Green Revolution has begun: Rice, food security, and climate change.* [Online]
Available at: http://irri.org/the-second-green-revolution-has-begun
[Accessed 21 August 2106].

IRD, 2016. *2015 Rapport d'activité,* Marseilles: Institut de Recherche pour le Développement.

IRD, 2016. *Antiretroviral treatment as a means of prevention against HIV.* [Online]
Available at: http://www.southern-africa.cnrs.ird.fr/science-in-southern-africa/research-

projects/antiretroviral-treatment-as-a-means-of-prevention-against-hiv
[Accessed 21 August 2016].

IRD, 2016. *Historique.* [Online]
Available at: http://www.ird.fr/l-ird/historique
[Accessed 21 August 2016].

IRD, 2016. *Impact of land management on organic carbon outputs from soils.* [Online]
Available at: http://www.southern-africa.cnrs.ird.fr/ird-sites-de-representation/afrique-du-sud/science-in-southern-africa/research-projects/organic-carbon-outputs-from-soils
[Accessed 21 August 2016].

IRD, 2016. *IRD et CNRS en Afrique Australe.* [Online]
Available at: http://www.afrique-australe.cnrs.ird.fr/
[Accessed 21 August 2016].

IRD, 2016. *La recherche.* [Online]
Available at: http://www.ird.fr/la-recherche
[Accessed 21 August 2016].

IRD, 2016. *Laboratoires Mixtes Internationaux (LMI).* [Online]
Available at: http://www.ird.fr/la-recherche/lmi-laboratoires-mixtes-internationaux
[Accessed 21 August 2016].

IRD, 2016. *Le renforcement des capacités de recherche des communautés scientifiques du Sud.* [Online]
Available at: http://www.ird.fr/les-partenariats/renforcement-des-capacites
[Accessed 21 August 2016].

IRD, 2016. *Les partneriats.* [Online]
Available at: http://www.ird.fr/les-partenariats
[Accessed 21 August 2016].

IRD, 2016. *Liste des observatoires des sciences de l'Univers/Flotte oceanographique.* [Online]
Available at: http://www.ird.fr/la-recherche/observatoires-flotte-oceanographique
[Accessed 21 August 2016].

IRD, 2016. *Upscaling understanding of water movement, land degradation and Carbon Cycle in support of effective Payment for Ecosystem Services.* [Online]
Available at: http://www.southern-africa.cnrs.ird.fr/ird-sites-de-representation/afrique-du-sud/science-in-southern-africa/research-projects/water-erosion-and-soil-degradation
[Accessed 21 August 2016].

IRD, 2016. *Valorisation et transfert de technologies.* [Online]
Available at: http://www.ird.fr/les-partenariats/valorisation-et-transfert-de-technologie
[Accessed 21 August 2016].

ITU, et al., 2012. *Science, technology and innovation for sustainable development in the global partnership fo development beyond 2015 - Thematic Think Piece,* s.l.: UN System Task Team on the post-2015 UN Development Agenda.

Jentsch, B. & Pilley, C., 2003. Research relationships between the South and the North: Cinderella and the ugly sisters?. *Social Science & Medicine,* 57(10), pp. 1957-1967.

Jones, T., Huggett, S. & Kamalski, J., 2011. *Finding a Way Through the Scientific Literature: Indexes and Measures,* s.l.: Elsevier.

Moedas, C., 2016. *Science Diplomacy in the European Union.* [Online]
Available at: http://www.sciencediplomacy.org/perspective/2016/science-diplomacy-in-european-union
[Accessed 21 August 2016].

OECD, 2012. *Innovation for Development: A Discussion of the Issues and an Overview on Work of the OECD Directorate for Science, Technology and Industry,* s.l.: s.n.

OECD, 2016. *Main Science and Technology Indicators.* [Online]
Available at: http://www.oecd-ilibrary.org/science-and-technology/data/oecd-science-technology-and-r-d-statistics/main-science-and-technology-indicators_data-00182-en
[Accessed 21 August 2016].

Pandor, N., 2012. *South African Science Diplomacy.* [Online]
Available at: http://www.sciencediplomacy.org/perspective/2012/south-african-science-diplomacy
[Accessed 21 August 2016].

Parker, C. B., 2016. *Cooperation of U.S., Russian scientists helped avoid nuclear catastrophe at Cold War's end, Stanford scholar says.* [Online]
Available at: http://news.stanford.edu/2016/06/28/cooperation-u-s-russian-scientists-helped-avoid-nuclear-catastrophe-cold-wars-end-stanford-scholar-says/
[Accessed 21 August 2016].

Republic of Kenya, 2008. *Science, Technology and Innovation Policy and Strategy,* Nairobi: Ministry of Science and Technology.

Ruffini, P. B., 2016. *La diplomatie scientifique, nouvelle dimension des relatoins internationales,* Le Havre: Campus France.

Salter, A. J. & Martin, B. R., 2001. *The economic benefits of publicly funded basic research:,* s.l.: Elsevier,

Sénat, 2016. *Projet de loi de finances pour 2016 : Action extérieure de l'État : diplomatie culturelle et d'influence.* [Online]
Available at: http://www.senat.fr/rap/a15-166-2/a15-166-210.html
[Accessed 21 August 2016].

SJR, 2015. *International Science Rating.* [Online]
Available at: http://www.scimagojr.com/countryrank.php?year=2015
[Accessed 21 August 2016].

Sooryamoorthy, R., 2009. *Science and scientific collaboration in South Africa: apartheid and after,* s.l.: Springer Netherlands.

The Royal Society, 2010. *New frontiers in science diplomacy: Navigating the balance of power,* London: The Royal Society.

UIS, 2005. *What do bibliometric indicators tell us about world scientific output?,* s.l.: UNESCO.

UNESCO, 1999. *The Role of Science and Technology in Society and Governance.* Budapest, UNESCO.

UNIDO, 2005. *Capability building for catching-up: Historical, empirical and policy dimensions,* s.l.: United Nations Industrial Development Organization.

Voeton, J., 2015. *Promoting Human Capital and Innovation in,* s.l.: Tilburg University.

Water.org, 2016. *Facts About Water & Sanitation.* [Online]
Available at: http://water.org/water-crisis/water-sanitation-facts/
[Accessed 21 August 2016].

Watson, R., Crawford, M. & Farley, S., 2003. Strategic Approaches to Science and Technology in Development. *World Bank Policy Research,* Working Paper(3026).

World Bank, 2016. *World Development Indicators,* s.l.: World Bank Group.

World Economic Forum, 2015. *Competitiveness Rankings.* [Online]
Available at: http://reports.weforum.org/global-competitiveness-report-2015-2016/competitiveness-rankings/
[Accessed 21 August 2016].

World Economic Forum, 2015. *The Global Competitiveness Report: 2015-2016,* Geneva: World Economic Forum.

World Economic Forum, 2015. *The Global Information Technology Report 2015,* Geneva: World Economic Forum.

World Food Program, 2016. *Hunger Statistics.* [Online]
Available at: https://www.wfp.org/hunger/stats
[Accessed 21 August 2016].

Zentrum für Soziale Innovation , 2013. *Egypt.* [Online]
Available at: https://caast-net-plus.org/policy_context/sti_systems_africa/egypt
[Accessed 21 August 2016].

Zentrum für Soziale Innovation , 2013. *Nigeria.* [Online]
Available at: https://caast-net-plus.org/policy_context/sti_systems_africa/nigeria
[Accessed 21 August 2016].

Zentrum für Soziale Innovation, 2013. *South Africa.* [Online]
Available at: https://caast-net-plus.org/policy_context/sti_systems_africa/south_africa
[Accessed 21 August 2016].

8. APPENDIX

8.1. Appendix 1: Charter for North-South Partners (Gaillard, 1994)

- The collaboration should be based on a strong mutual interest and both partners should have something gain from it.
- Project proposals should, whenever possible, be drafted jointly and each partner should be involved as much as possible in the important decisions to be taken.
- In particular, decisions on specific instrument purchases should be made jointly and the necessary provision for installation, maintenance and repair should be secured.
- Provision should be made in the budget for a training component, and research training should, whenever possible, take place as part of a formal degree programme to increase commitment.
- Salaries should be sufficient to ensure full-time commitment, or complemented by supplementary means (e.g. research honoraria) secured in the budget.
- Transparency should be a golden rule between the partners, e.g. both sides have information on the budget allocations to each side and how funds are being spent.
- Each cooperating group should delegate a substantial number of researchers (at least three).
- Both parties should meet regularly to review ongoing work and plan future activities.
- Fast communication channels (e.g. fax and e-mail) must be available to ensure efficient interaction between partners.
- Scientific papers should be written jointly, with the names of the authors from both sides appearing on the published papers.
- Collaborative programmes should be evaluated on a regular basis, e.g. after each phase is completed.
- Monitoring should emphasize project outputs rather than inputs.
- Mechanisms should be established so that the collaboration can continue after the collaborative programme is terminated to ensure a long lifetime to the collaborative partnership.

8.2. Appendix 2: Alphabetical list of various bibliometric indicators[5]

Bibliometric	Definition	Advantage	Disadvantage
Article Influence Score	Measures the average influence, per article, of the papers in a journal; provides a standardized Eigenfactor score	Reduces or removes large differences between fields evident in IF	Dependent on the number of articles published
AWCR	A measure of average number of citations for an entire body of work, adjusted for the age of each individual paper.	Actual number of citations are taken into account Makes use of age of publication Can be used with h-index to complement its accuracy	
Crown Indicator	Developed by Centre for Science and Technology Studies (CWTS) at Leiden University. Average number of received citations (from a researcher or a research group) divided by the average number that could be expected for publication of the same type published in journals within same field.	Allows comparison of researchers in different fields Controls for citation rate in research field, document type and publication year; thus overcoming the limitations of IF	Not readily available Does not take into account the fact that articles from one field are published in journals of different field Only allows comparison of equal-sized research groups
Eigenfactor Score	A journal indicator that is 'an estimate of the percentage of time that library users spend with that journal'	Easily available	Does not take into account the scientific value of a journal
g-index	The highest number *g* of papers that in total	Takes into account the citations that are ignored by h-index	Puts more weight on highly cited papers

[5] (Froghi, et al., 2012)

	received g^2 or more citations	Avoids subsequent counting of top cited h papers	
h-index	Proposed by Hirsch: 'A scientist has index *h*, if *h* of his/her (N) papers have at least h citations each, and the other (N-h) papers have no more than h citations each'	Readily available Insensitive to extremely rare or frequently cited articles Allows comparison of faculty of different ranks	Depends on the age of the researcher/scientific career Variable from one discipline to another Does not take into account the position in the author list Sensitive to homonym conflicts Insensitive to highly cited work
***m* quotient**	*m*=*h*/year where *h*= h-index and*yr*= number of years since publishing the first paper	Allows h-index to compare faculties of different rank	Insensitive to highly cited work An unstable index for junior researcher as it takes into account the year of publication; thus large changes in *m* quotient can result from small changes in h-index

8.3. Appendix 3: R&D Indicators of Egypt, Ethiopia, Nigeria and South Africa[6]

INDICATOR	EGYPT	KENYA	NIGERIA	SOUTH AFRICA
GERD (% of GDP)	0,67868	0,78578	0,21896	0,73168
ITA score/rank	0.124/47	0.044/74	0.012/96	0.206/33
GCI score/rank	3.7/116	3.9/99	3.5/124	4.4/49
Network Readiness Index score/rank	3.6/94	3.8/86	3.2/119	4.0/75
Global Innovation Index score/rank	26.0/107	30.4/80	23.1/114	35.8/54
Charges for use of IP: Payments/Receipts (BoP, current '000s US$)	241,500/ 122,000	147,498/ 59,651	250,794/ …	1,708,386/ 103,118
Scientific & Technical journal articles	9,199.2	871.6	3,653.7	9,679.1
National H-Index (2015)	184	179	131	320
Patent Applications: residents/non-residents	752/1,384	132/75	50/869	802/6,750
Trademark Applications: residents/non-residents	11,390/8,161	2,816/1,808.0	19,332/…	20,475/14,943
Researchers in R&D (per million people)	681	231	38	404
Technicians in R&D (per million people)	355	654	13	125

6 Data from http://data.uis.unesco.org/?queryid=74
Data aggregated from the following sources:
(World Bank, 2016), (UNIDO, 2005), (SJR, 2015),(World Economic Forum, 2015),(Cornell University; I NSEAD; WIPO, 2016), (OECD, 2016)

8.4. Appendix 4: STI Cooperation Questionnaire

1. **STI Cooperation Questionnaire**

   This questionnaire forms part of an internship research report for the Institut de Recherche pour le Développement (IRD). The aim of this report is to understand the role and importance of science, technology and innovation (STI) in the development of the Global South.
   This questionnaire is targeted at professionals involved in North-South and South-South STI cooperation projects and aims to understand the dynamics between partner institutions from the personal point of view of the respondent.

   The questionnaire should take between 10 to 15 minutes to complete.

   Available at https://goo.gl/forms/5pJxAbE3Kuc9Mcwj2

2. **Education & Mobility**
   - Education level
     - Bachelor
     - Honours
     - Masters
     - PhD
   - Field of study
     - Mathematics
     - Biology
     - Chemistry
     - Earth Science
     - Engineering & Technology
     - Medical & Health Science
     - Social Science
     - Humanities
     - Other
   - How much time have you spent outside your country of origin?
   - Which are the 3 countries that you visit the most for professional purposes?
   - What is your current professional location?
3. **Professional Engagements**
   - In which country are the headquarters of your home institution based?
   - Which phrase qualifies your home institution the most accurately?
     - Public University
     - Private University
     - Public Institute
     - Private Institute
     - Non-Governmental Organisation (NGO)
     - Other
   - What is your job title?
   - In which field/industry do you work?
   - How related is your work to the development of emerging economies?
     - Scale from 1 to 10. 1=not related at all, 10=entirely related

4. STI Cooperation Project

- Are you currently involved in an STI cooperation project?
  - Yes
  - No
- Which partner institutions are involved?
  - Scale from 1 to 10. 1=all from developed countries, 10=all from emerging economies
- In which way is this project related to development?
  - Public policy consulting
  - Innovation enabling
  - Capacity building
  - Economic development
  - Employment creation
  - Other
- What type of research output is this project creating?
  - Scale from 1 to 10. 1=basic science, 10=applied science & technology development
- What proportion of the project staff comes from your institution?
- How important is this project to your institution, relative to other projects?
  - Scale from 1 to 10. 1=least important, 10=most important
- Is this project important to your work, relative to other professional engagements?
  - Scale from 1 to 10. 1=least important, 10=most important
- What does your institution gain from the partnerships in the scope of the project?
- How involved was your institution involved in drafting the proposal for the project?
  - Scale from 1 to 10. 1=not involved at all, 10=drafted the entire proposal
- How involved is your institution in making important decisions concerning the direction of the project?
  - Scale from 1 to 10. 1=not involved at all, 10=makes all the decisions
- How involved is your institution in making decisions about equipment purchases?
  - Scale from 1 to 10. 1=not involved at all, 10=makes all the decisions
- How involved is your institution in making decisions about the installation, maintenance and repair of equipment?
  - Scale from 1 to 10. 1=not involved at all, 10=makes all the decisions
- How much of the budget is allocated to a training component?
- How much of the training component is part of a formal degree programme?
- How much financial transparency is there between partners?
  - Scale from 1 to 10. 1=no transparency, 10=complete transparency
- How regularly do partner institutions meet to review ongoing work?
  - Never
  - Daily
  - Weekly
  - Yearly
  - Other

- How regularly do partner institutions meet to plan future activities?
    - Never
    - Daily
    - Weekly
    - Yearly
    - Other
- How efficient is the communication between your institution and the other partners involved in the project?
    - Scale from 1 to 10. 1=no communication, 10=perfect communication
- What is the proportion of publications from this project that are co-authored?
- How are intellectual property rights shared between partners in this project?
    - Scale from 1 to 10. 1=using research best practices, 10=formalised IP agreement
- Is the project monitoring focused more on inputs or on outputs?
    - Scale from 1 to 10. 1=completely focussed on inputs, 10=completely focussed on outputs
- Does this project include the possibility of renewal?
    - Yes
    - No
    - Other

5. **Concepts for STI in Development**
    - Which factor hinders development the most in the country you are working in?
        - Agriculture
        - Health
        - Water
        - Environment
        - Other
    - Which of the following is the least developed in the country where you work?
        - Human capital
        - Knowledge demand from the private sector
        - Public sector support for STI
        - Information & Communication Technologies
        - Other
    - How successful is the "diaspora" network model to reverse the brain-drain in the country you are working in?
        - Scale from 1 to 10. 1=inexistent network, 10=fully functional network
6. **Demographic Information**
    - Full Name
    - Email Address
    - Year of Birth
    - Sex
        - Male
        - Female
    - Country of Citizenship