SCIENCE, TECHNOLOGY AND INNOVATION (STI) POLICY TRAINING FOR AFRICA:

A BASIC MODULE ON RECONCILING THEORY, PRACTICE AND POLICIES

a Handbook Prepared by

The Science, Technology and Innovation Policy Research Organization (STIPRO)
on Behalf of the ACTS Consortium under the Science Granting Councils' Initiative (SGCI),
Theme III

Authors:

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May 2019

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List of Abbreviations

ACTS	African Centre for Technology Studies
ASTII	African Science, Technology and Innovation Indicators
AIO	African Innovation Outlook
CRES	Assistante de recherche au Consortium pour la Recherche Economique et Sociale
ECOWAS	Economic Community of West African States
DFID	Department for International Development
DUI	Doing, Using and Interacting
DNA	Deoxyribonucleic Acid
DARPA	Defense Advanced Research Projects Agency
GERD	Gross Domestic Expenditure on Research and Development
GDP	Gross Domestic Product
IPRs	Intellectual Property Rights
ICT	Information and Communications Technology
IPCC	Intergovernmental Panel on Climate change
IS	Innovation systems
LDCs	Least Developed Countries
MEL	Monitoring, Evaluation and Leaning
M&E	Monitoring and Evaluation
NEPAD	New Partnership for Africa's Development
NSI	National Systems of Innovation
NSF	National Science Foundation
OECD	Organization for Economic Co-operation and Development
R&D	Research and Development
REPOA	Research on Poverty Alleviation
STIPRO	Science, Technology and Innovation Policy Research Organization
STI	Science, Technology and Innovation
SGCs	Science Grating Councils
SPRU	Science Policy Research Unit
SDGs	Sustainable Development Goals
S&T	Science and Technology
SoSP	Science of Science Policy
STISA	Science, Technology and Innovation Strategy for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
WIPO	World Intellectual Property Organization
WHO	World Health Organization

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Background

This is the first and basic training module on science, technology and innovation (STI) policy for Africa to be produced by the ACTS Consortium/STIPRO as part of the outputs for their work on theme III of the Science granting Councils' Initiative (SGCIs). We therefore find it fruitful – by way of background information – to inform on three major issues, namely the understanding of the critical importance of innovation in Africa's development by the Africa's governments; why is policy important; and why this specific module on reconciling theory, practice and policies. We feel this helps in building a strong foundation on which subsequent STI policy trainings can be built.

Why is Innovation Important?

Innovation – briefly defined as implementation of new or improved ideas in social and economic settings – has long been broadly accepted as being central to the social and economic development of countries. However, achieving a high level of innovation capabilities by countries has to a large extent been an up-hill battle. But the foundation is for governments to understand why it is important, and therefore commit to it: Innovation, by industries, service providers and other economic/productive sectors, contributes to sustainable GDP growth and generates employment; and if this is made inclusive, it becomes a powerful means through which poverty is radically reduced in a country. According to Ahlstrom (2010), a vibrant, innovative and inclusive private sector is more important for the wellbeing of a nation than any foreign aid and welfare redistribution programs. However, under the current dominance of market economy and globalization, this potential for the private sector to cater to the general welfare of a country is compromised if national companies are not innovative; this is because other countries' firms who are innovative, and therefore producing higher quality goods with lower prices, can dominate a country's domestic market. We have witnessed this for many products in Africa, e.g. clothing, drugs and healthcare products, edible oil and other processed food products. Some of these products are from low-tech sectors where innovation is not that difficult or expensive – it just requires design and implementation of good policies.

In most countries nowadays, poverty and the country's competitiveness – both in domestic and export markets – are connected; hence it is argued that the country that can overcome poverty is the one that is ever dynamically innovative. This has negative implications on Africa's industrialization agenda and efforts of poverty alleviation, especially because local firms in most African countries currently have very low levels of innovation capabilities. According to existing studies, (e.g. NEPAD 2010, 2014; Cirera and Maloney 2017) African firms innovate only through minor incremental innovations and imitations of low-tech technologies. A Tanzanian study (Diyamett, 2010) indicates that a good percentage of Tanzanian metal industry firms are innovative, but largely in only small incremental innovations and imitations. In addition, when innovation takes place, it is not achieved through advanced planning and proactive search for knowledge, but rather through routine activities of producing and selling. Such trends could be dangerous, given the current global environment of rapid changes in technology towards more sophistication, as the ability to compete requires intentional and planned work. With low innovation capabilities, less potential for new firms emerging, and less employment generated, there is less demand for innovative and high-quality goods and services because people have small and static purchasing power due to unemployment; this in turn exacerbates an environment of poor innovative activities. A vicious cycle of low levels of innovation and high levels of poverty is created. Africa must find a way of addressing this cycle.

Why is Policy Important?

While some selected STI policies are important for all countries worldwide, for Africa they are indispensable. This is because – largely as symptoms of poverty – there are both market and innovation system failures, and therefore the production, dissemination, and use of economically useful knowledge cannot be left to the play of the market alone; governments' hand in terms of carefully crafted policy directives, is required. There are further details on why policy is important, explored later in this module.

Importance of Reconciling Theory, Policies and Practice; and Why SGCs

It is broadly accepted that poverty in developing countries, Africa inclusive, is largely a result of low national technological and innovation capabilities—defined as the ability to make effective use of technological knowledge in efforts to assimilate, use, change existing technologies, and introduce new ones to the market (Diyamett and Mutambala, 2014; definition adapted from Kim, 1997). According to Xavier and Maloney (2017) one major reason for such low capabilities is weak capabilities in STI policymaking—an underappreciated component. The major intention of this STI training workshop handbook is to contribute to addressing this policy problem, specifically targeted at reconciling theories, policies and practice. Such a need is based on the premise that theories are essential tools for policymaking; many scholars of public policy convincingly argue that most policy debates ultimately rest on competing theoretical visions. According to Stivachtis (2013) for instance, theory remains essential for diagnosing events, explaining their causes, prescribing responses, and evaluating impacts of different policies. In other words, good and evidence-informed policies must rely on facts brought to the fore through scientific research, and, as we know, scientific research is usually based on some theoretical and/or conceptual lenses, themselves possible derived from practice (or verified through it). In the words of Fagerberg (2015), if theoretical work seeks to be relevant for policy, it has to be based on assumptions that are broadly consistent with empirical evidence from realities. This leads to the established notion of the strong interconnections between theory, practice and policies, stressed in this volume.

The module of this handbook is also proposed as a result of our own experience in interacting with policy makers in a number of African countries, including participating in STI policy designs and reviews. From such experience it became clear that, to a large extent, understanding of some of the terminologies in the STI concepts and theories can be a major stumbling block in STI policy design, implementations and monitoring activities. Innovation is context specific in the sense that what works (practice) in one context does not necessarily work in other contexts, and so is innovation theory; and therefore, relying on theories that are not tested or verified in particular contexts for policymaking can lead to STI policy disasters. A good example is the early United States' S&T policy that followed a linear model (theory) of the technology push, where science was believed to be an endless frontier—that to spur social and economic development all that governments need to do is put more money into scientific research and discoveries, and social and economic wellbeing automatically follow. The model was a result of the success of the United States' military science in achieving predetermined military goals, such as the Manhattan project (the atomic bomb). However, as a result of new empirical evidence, the linear model was later criticized as an inappropriate tool for analyzing the overall innovation processes in a country, except for some mission oriented programs; but even with these, to be successful programs have to go hand in hand with some market shaping and fixing policy instruments (Mazzucato, 2018). Following these new findings, countries, especially rich ones, have moved on to systems thinking as far as innovation is concerned, while most of Africa is still stuck with this linear model. This training module was therefore designed to address these critical conceptual issues, especially those around connecting knowledge (scientific research) to use by productive sectors in low-income countries such as most African countries. To be effective, such theoretical and conceptual issues will be discussed in light of current practices and experiences of countries in designing, implementing and monitoring their STI policies.

STI policy issues are myriad and diverse, yet this handbook is meant to build a foundation on the analysis of these issues – especially by the science granting councils who are responsible for research orientation and management in countries. It deals only with basic conceptual issues surrounding the concept of innovation – especially the role of demand for knowledge, and the interactive learning among important system actors, largely those responsible in connecting research to productive activities. The triplet of STI and the interrelationships between individual components will also be explained, as this clearly brings to the fore the relationships between research and innovation in different social and economic settings. The policymaking process itself and the relationship between theory and policy will also briefly be taken up; this is because in most cases this relationship is neither clearly understood nor valued, not only by policy makers but also by researchers themselves. It is quite normal to hear the statement: "do not bring in theories here, we want practical things," not realizing that those practical things, always – whether consciously or unconsciously – have some mental maps (conceptual thinking) behind them. For instance, the origin of current emphases on the supply side (i.e. investments in R&D) in most STI policies in Africa comes from the linear model of technology push (i.e. science being the "endless frontier") that originated in the US, especially influenced by the passing and success of the Bayh-Dole Act in the U.S. From there, other countries, including poor developing countries, followed suit, in the following decades, in making investment in science a major indicator of innovation (Huang, et al., 2010).

The intention of the module is to foster and stimulate, as much as possible, conceptual thinking that is as close to the realities of the underlying problems that STI policies try to address in African contexts.

A practical example of the impact of inadequate understanding of conceptual issues around science, technology and innovation theories is the use of triplet "STI" as one thing by most policy technocrats in Africa, rather than discerning that it is three things that are different but closely related. Such lumping together of the three components of the triplet has rendered many STI policies in Africa too ambiguities. For instance, STI policy instruments such as funding and capacity building have in most cases only focused on researchers, completely ignoring the component I (innovation) that takes place mostly in productive sectors and it is what counts when it comes to impacting people's lives.

In regard to why mainly targeting science granting councils (SGCs) for this training, the rationales for that are several. To start with, SGCs are crucial actors in national systems of innovation; they have a critical role to play in STI policy frameworks. While some councils are directly involved in policymaking processes, others – like in Tanzania – are principal advisors to the government on policy issues. However, most of the SGCs in Africa – if not all – are involved in the development and use of STI indicators, and one important use of STI indicators is to inform policy; hence it is fruitful for SGCs to have some basic understanding of the policy process and conceptual models that inform it. Another rationale – perhaps most important – for the need for SGCs to understand the policy process comes from the fact that all councils are involved in research management, and one of the very crucial STI policy issues for Africa is how to link research to use. SGCs, as key actors in national innovation systems, are well placed to address this issue. For all the above, it is critically important for the SGCs to be conversant with the STI policymaking process.

This module has been designed to enable SGCs, and similar or related key actors, to have a clear understanding of the theoretical and conceptual issues surrounding the design of needed STI policies with appropriate instruments for Africa. Special consideration has been given to the system elements that are most relevant to linking scientific research to activities of the private (or non-state) sector in environments of poor countries, such as those in Africa.

Introduction to the Module

The overall objectives of the module are:

i) Participants to appreciate the role of theory and conceptual understanding of STI in the policy process or action they intend to take in an effort to close the gap between scientific research and the productive activities.

ii) Participants to understand the interrelationships between individual components in the concept of STI, how these interrelationships depend on a given social and economic context, and what this means for research policy in African contexts.

iii) Participants to understand forces behind innovative activities and the role of knowledge (scientific research) in the process.

iv) Participants to understand the linkages between scientific research and productive activities in different socio-economic settings.

v) Participants to revisit current policymaking processes in their own countries so as to reconcile theory and practice and propose appropriate policy options and instruments for their implementation.

Expected outcomes

By the end of the module participants should be able to:

i) Understand the connection between theory, policy and practice; and make use of theory and evidence in understanding and addressing STI policy problems, their causes and in selecting appropriate policy instruments to address such problems.

ii) Understand and distinguish different between conceptual issues on science, technology and innovation, and how these issues inform policies on the linkage between research and innovation.

iii) Understand, and make use of, the crucial role of policy research in the policy process.

iv) Develop and provide advice to their governments on issues related to STI policies.

v) Develop and implement effective university-industry linkage programs in their countries.

Module Units

Module units are according to the above topics – one topic forming a unit. Following units will be covered:

i) Conceptualizing science, technology and innovation: History and interrelationships between the three components of STI in different social and economic settings.

ii) Historical account of innovation models and associated innovation policy shifts: from linear model of push and pull types, to systems of innovation and the relevance to the African context

iii) The overall policy process: agenda setting, policy formulation and adoption, policy implementation, and monitoring and evaluation and learning.

iv) The role of research and evidence in the policymaking process: science of science policy.

UNIT 1: UNDERSTANDING INNOVATION AND THE INTERRELATIONSHIPS BETWEEN SCIENCE, TECHNOLOGY AND INNOVATION (STI)

Unit objectives
To foster and stimulate better understanding of the conceptual issues surrounding the concept of STI and how the three elements of the triplet – science, technology and innovation - are interrelated among policy technocrats. It is anticipated that better understanding on how the three elements are interrelated in different social economic setting will lead to better policy designs and choices of policy instruments.

Unit topics to be covered
Understanding the concept of innovation; types and degrees of novelty of innovation; interrelationships between science, technology and innovation; and a historical perspective on the concepts of modes of innovation: DUI (doing, using and interacting) and STI, which explains how innovation of different degrees takes place in social and economic activities.

Unit expected outcome
It is expected that understanding of these concepts will help participants to better contribute to the process of STI policymaking. It will also help them in setting research policy agenda, including priority setting and managing linkages between research and productive sectors in the environment of a poor developing country such as those in Africa.

1.0 Understanding Innovation

Innovation can succinctly be defined as successful application of ideas that are novel and useful. In economic terms – where innovation terminology is largely being used – **innovation is defined as successful creation, development, and marketing of new products or successful application of new techniques or ways of working that improves the effectiveness of an individual and organization** (Archibugi et al., 1994). Four major types of innovation have been identified within this definition as: i) product innovation, ii) process innovation, iii) market innovation, and iv) organizational innovation. The 4th edition of the Oslo manual (latest) has collapsed these four types of innovation into two, namely product and business process innovation, with business process representing the other three types of innovation (OECD/Eurostat, 2018).[1]

Before we move into brief explanation of the above types of innovation, it is important to make a terminological distinction between innovation and invention – two terminologies that are often confused for each other and interchangeably used. They are two different

[1] For more information on why these changes and the comparison between the 3rd and 4th edition of the Oslo manual, please consult the 4th edition of the manual, from pg 75.

things, however, although of course interrelated: while invention refers to the creation of something new, **innovation** is the actual introduction/deployment of a new thing into the marketplace or any other useful practice. A scientific breakthrough at the university laboratory may form a good invention, but it needs some extra efforts to take such invention to the market or apply them in solving some challenges facing humanity; sometimes a discovery like that will require another complimentary, new discovery or discoveries, to emerge before it can be put into use. For instance, the discovery of the double helix DNA molecular structure by Watson and Crick in 1953 was one of the most celebrated historic inventions, but there was no commercial application of such invention until the recent emergence of biotechnology industries. The key message from this case is that, it may take a while for an invention to mature into an innovation. In addition to that, when an invention is finally put into use there are normally many innovations that can occur slowly with a series of major and minor improvements as the product or idea diffuses through given social and economic settings. Both the generation of inventions and their translation into practical solutions requires suitable environments and proper policies; these includes internal policies within the innovating firm and external policies to enhance the enabling environments for innovating firms to succeed. Such external policies are normally overseen by governments and are a major focus of this volume.

1.1 Types of Innovation

From the definition of innovation above, 4 types of innovation can be identified as follows:

Product innovation

A product innovation is the introduction of a product that is new or significantly improved with respect to its characteristics or intended uses. In this context a product could be a good or service. Product innovation includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics. Innovation requires money, so new products are not likely to be introduced haphazardly; a new product has to solve an existing problem in a new way or solve a new problem that has arisen. An example of product innovation when at the 2016 Consumer Electronics Show, the company LG introduced a new type of screen that is so flexible you can roll it up like a newspaper. Such innovative product solves the problem of portability (i.e. instead of using a larger, unwieldy screen, people can use a screen that they can fold up when they are done and put it in their bag).

When measuring innovations there could be some minor changes to products that may not be considered innovations. The thresholds and definitions of what qualifies depend on the standards set by a defining agent and the purpose of the classification. For instance, according to OECD innovation indicators, as guided by the Oslo Manual, some minor changes to a product's packaging are not considered innovations. It should also be noted that products are not only tangible physical objects, there are also some non-tangible products. For example, the introduction of Islamic bank accounts for the first time in a country, or any relatively new banking system, could be regarded as a product innovation.

Process innovation

A process innovation is the implementation of a new or significantly improved production or delivery method. This also includes significant changes in techniques, equipment and/or software. Process innovation helps in cutting production costs and may sometimes lead to the development of new products. The Swedish furniture firm IKEA, for example, innovated its product assembly process by delegating it to the consumers. As a result of IKEA's process innovation, their furniture became cheaper, portable and offers customers flexibilities on setup parameters such as height and width during assembly on-site.

Organizational innovation

This form of innovation involves increase in quality and efficiency of work, improvement in information sharing behavior and the ability of the firm to use new technologies, so as to increase the productivity of investment in knowledge. It includes changes in organizational behavior, internal and external relations and other organizational methods. In the case of public organizations, organizational innovation tends to be related to good governance, accountability and enhancement of performance with efficient use of resources. Things like outsourcing, decentralization, introduction of new procedures and new structures are examples of organizational innovation.

Marketing innovation

OECD defines marketing innovation as the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. Marketing innovations are aimed at better addressing customer needs, opening up new markets, or positioning a firm's product on the market in a new way, with the objective of increasing the firm's sales/standing.

According to the 4th edition of the Oslo manual (OECD, 2018) that uses business process innovation in place of the three other types (in addition to product innovation), business process innovation represents 6 different business functions as follows:

i) Production of goods or services activities that transform inputs into goods or services, including engineering and related technical testing, analysis and certification activities to support production
ii) Distribution and logistics, which include: a) transportation and service delivery, b) warehousing, and c) order processing
iii) Marketing and sales functions, which include: a) marketing methods including advertising (product promotion and placement, packaging of products), direct marketing (telemarketing), exhibitions and fairs, market research and other activities to develop new markets; b) pricing strategies and methods; and c) sales and after-sales activities, including help desks other customer support and customer relationship activities.
iv) Information and communication systems: the maintenance and provision of information and communication systems, including: a) hardware and software, b) data processing and database, c) maintenance and repair, and d) web-hosting and other computer-related information activities. According to OEDC, these functions can be provided in a separate division or in divisions responsible for other functions

v) Administration and management. This function includes: a) strategic and general business management (cross-functional decision-making), including organising work responsibilities; b) corporate governance (legal, planning and public relations); c) accounting, bookkeeping, auditing, payments and other financial or insurance activities; d) human resources management (training and education, staff recruitment, workplace organisation, provision of temporary personnel, payroll management, health and medical support); e) procurement; and f) managing external relationships with suppliers, alliances, etc.

vi) Product and business process development. These are activities that scope, identify, develop, or adapt products or a firm's business processes. According to the OECD, this function can be undertaken in a systematic fashion or on an *ad hoc* basis, and be conducted within the firm or obtained from external sources; and responsibility for these activities can lie within a separate division or in divisions responsible for other functions, e.g. production of goods or services.

Business process innovation can take place with changes in any of the above functions – either improved or completely new.

1.2 Degrees of Novelty in Innovation

Innovation can be of differing degrees of novelty. It can be completely new – coming from a completely new scientific discovery, such as a discovery of the DNA double helix alluded to above, or the invention of the transistor which was the basis of the emergence of the whole IT industry. Later there can be some major subsequent discoveries within the new industry, such as subsequent discoveries within the IT industry.

Innovation can also be incremental (modifications of existing technology). According to the OECD (2004), incremental innovations are those changes in products and processes that are insignificant, minor or do not involve a sufficient degree of novelty. It is a source of technological innovation that is usually not explicitly recognized as a component of the R&D process, which overlaps with the development stage and receives no direct expenditure (depending on the level of novelty in the modification). Examples are when most mobile phone manufacturers release a new version of their phones every few years, with only minor changes or improvements.

Included also in the degree of novelty of an innovation is adoption of a technology developed by someone else without changing it; this means that firms can adopt processes and product technology without changing anything. If they are successfully introducing these products and processes for the first time in their context, they are classified as innovators (Rosenberg 1982; Rogers 1983; Coombs et al., 1987). In other words, innovative ideas do not need to be novel in the absolute sense of the term as long as they are new in the context in which they are being exploited. It is worth noting here that spurring both novel and incremental innovations require policies, but with slightly different policy instruments and actors targeted in the national innovation system. While for incremental and adoptive kinds of innovation the major policy focus should be on innovators themselves (firms and farms), for the innovation coming from radically novel ideas, R&D is crucial, but should be balanced with instruments on the demand side (firms and farms), and some linkage related instruments. This point will further be explained, when we talk about the relationships in science, technology and innovation, and in STI and DUI innovation models. Policy instruments will be addressed further in unit three.

While innovation of higher degrees of novelty are very attractive and important for social and economic development, in practice there is no short cut in achieving them. Historical experience indicates that innovation capabilities have always been gradually built, moving up from the lowest level of adoption to the highest level of fundamental change (creation of radically new things). The history of Japan is instructive here: between the 1920s and 1970s when Japanese largest firms were catching up to industrialized western countries, their technological capabilities were initially basic and highly adoptive, merely grounded on the achievement of operational efficiency and standard product designs. However, over time, they steadily became more complex and sophisticated, and increasingly became knowledge intensive. In the course of this transition, the country increasingly relied on knowledge creation and absorption, leading to the development of internal R&D capabilities (Diyamett, 2010). Other examples are that of Sweden, Norway and Finland. Sweden shifted from iron ore production to iron and steel industries, to fabricated metal products (most notably cars and trucks) and then to machine tools and electronic systems. Norway moved from marine transport, to shipbuilding, then to marine electronics and developing the world's first automated navigation systems and continuing to be a leader in surface and sub-sea marine applications. Finland went from paper production to chemicals for paper, and then to paper machinery (a major sector in which it is a world leader) (Smith, 2006).

This process of gradually moving up the innovation capability ladder can be depicted diagrammatically as shown in Figure 1, below. Even nowadays, different firms, countries and regions can be placed at different stages indicated in the diagram.

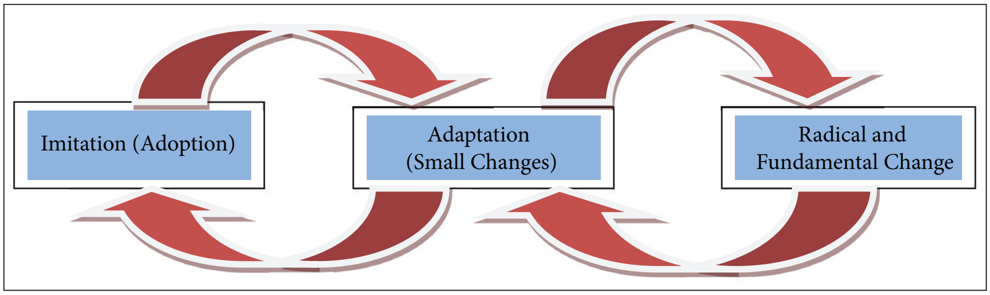

Figure 1: The Process of Innovation Capability Building
Source: Adapted from Diyamett, 2010.

In relation to the above diagram what has changed or should be changed today is time taken to move from one level to the other, and not so much of skipping the levels. In the older days where technological change was much slower, without the prevalence of globalization and free market economy rules, countries took their time to learn and slowly moved up the innovation capability ladder. However, nowadays, in the environment of globalization and rapid technological change, countries and firms do not have the luxury of taking their time to learn; they need to learn faster or otherwise they will be overtaken by events and outcompeted. A carefully crafted innovation policy is of absolute necessity to address these challenges.

1.3 Relationships Between Science Technology and Innovation (STI)

To have a good grasp on how moving up in innovation capabilities happen in practice, and how policies for such movement can be designed, it is extremely important to understand the relationships between science, technology and innovation, and how the surrounding social and economic contexts affect these relationships.

As already alluded to, the concept of STI is to a large extent being wrongly used as one thing, while in fact the concept is made up of three, distinct, interrelated, things: science, technology and innovation. The use of this triplet as one thing has in most cases brought ambiguities in the STI policy because the three elements happens in relatively three distinct spaces with different functions in society: science happens often in higher learning spaces with the purpose of producing new knowledge; innovation happens in industrial spaces with the major aim to produce competitive products, thus enhancing incomes of countries; and technology can either happen in R&D spaces or industrial spaces depending on circumstances (i.e. while industrial firms use technology in the production and marketing process, R&D institutions develop new technologies). In this regard, when one makes a blanket use of the STI concept as one thing, what does one really mean in terms of policy and instruments to be used? Where is the focus, for instance, in terms of capacity building and funding: universities, R&D institutions, or industrial firms? Experience indicates that, in STI policy discourses in Africa, most attention is paid to universities and R&D organizations, with almost complete neglect of industrial firms and farms, where innovation – which is indispensable to development – takes place. In the following few paragraphs we make an attempt to explain the relationships between the three elements of science, technology and innovation, taking the relationships between two elements at a time.

Relationships between technology and innovation

While technology often refers to the making and usage of tools and techniques in order to solve particular problems or perform specific functions, technological innovation may refer to the implementation and deployment of technology outputs. Technological innovation is very much related to the concepts of technical change and technological change: when we talk of *technical change* and *technological change* we refer to changes that take place in technologies, which may or may not have direct impact on given social and economic conditions (depending on the technology type and the change type), but when we talk about innovation we confirm that consequent changes are taking place in social and economic activities. Innovation is therefore primarily a social process. In the innovation literature putting technologies and knowledge to use, economically and socially, is the focus. New technologies that are being created in our R&D organizations do not necessarily have impact in our lives unless they are being put in some socially and economically observable use. Accordingly, one of the very important innovation policy instruments concerns linking R&D organizations with the productive sector.

Relationships between technology and science

In regard to the relationship between the two above, there has been, and there still is a popular belief that science predated technology, and technology being simply conceived as application of science. However, history tells us a different story—that technology antedated science by far: when early people made fire out of friction, no one before that systematically investigated that friction between two objects can produce heat energy. It has been written many times that it is technology that gave birth to early scientific investigations on heat transfer and thermal energy, leading to discovering the scientific laws of thermodynamics. In chemistry, the science of polymer that emerged in the twentieth century, is largely attributed to the contribution of research performed inside industrial laboratories to develop materials that could better fulfill the changing requirement of industry (Richard, et al., 1993). The rise of scientific understanding supporting aircraft design reflects a similar story—a primitive version of the aircraft (technology) came first and the science discipline of aerodynamics followed (Richard, et al., 1993).[2]

However, gradually – with the emergence of modern technologies – the relationship between science and technology was intensified, and science became increasingly used in the development of technology. In modern times, the overlapping of science and technology is the norm, to the point that sometimes it is not easy to distinguish between scientific activities and technological activities. Good examples are modern, science-intensive and complex technologies such as the nanotechnology, biotechnology, computing and telecommunication technologies. The biotechnology revolution, for instance, has brought about an unprecedented convergence of science and technology. Therefore, to better explain the relationship between science and technology nowadays, we shall say that they have a symbiotic relationship: changes and advances in technology usher developments in science and vice-versa.

Science and Innovation

From the relationships mentioned above, we can see that there is a close relationship between science and innovation in the sense that science – through scientific research and new knowledge generated – is used to improve technologies that are in use or to create new ones that must be put to use to become innovations; that is, science is often used to innovate. That depends on the level of technology—if it is low-skill technology or based only on simple scientific concepts, then may be science is not that necessary to improve it. This brings us to the notion of two modes of innovation: DUI (doing, using and interacting) and STI (science, technology and innovation). Understanding the two modes is extremely important for the design and implementation of innovation policies in different social and economic contexts.

DUI and STI mode of innovation

Doing, Using and Interacting (DUI) and Science, Technology and Innovation (STI) modes of innovation are at the heart of innovation being a learning process. As best described by Lundvall (1992), the concept of learning is used in the salient features of innovation by invoking three forms of learning. First is "learning" in a strict sense—learning that originates in routine activities associated with the production, distribution and consumption functions of firms in the form of learning by doing, using, and by interacting

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[2] It is important to note here that innovation predominantly hinges on experiential learning through doing, using and interacting, thus neglecting the role of the productive sector, and of users more generally, in the innovation policy process is a serious oversight. This point is further expounded in the section on DUI and STI mode of innovation.

(DUI). Second is learning by "searching" through more formalized learning activities carried out by firms in their departments for market analysis and R&D laboratories. Third is learning by "exploring" which consists of research activities undertaken in academic or science-based organizations outside the private sector (Lundvall, 1992). The second and third form are normally referred to as the STI mode of learning or innovation. Empirical evidence on roles played by each mode in the innovation processes is fairly established. The DUI mode involves a degree of interaction within firms and between the firms and their environments. The learning process involves experiences and competences acquired by employees on-the-job as they face new challenges in the production and marketing functions to be addressed. Such learning may be derived from within firms or from customer experiences and other elements of the innovation process. DUI is built from the know-how and know-who experiences which are usually obtained outside the domain of R&D activities. It is a series of organizational actions during the production process; it is about transfer and application of experience-based knowledge and technology in order to adapt to changes in the environment. Experience indicates that DUI is largely used, and more frequently, by economies with low of innovation capabilities. Empirically, this is shown in Africa by the NEPAD innovation surveys, which found that about 60% of firms in Sub-Saharan African countries are innovative, however most of these innovations are adoptive and incremental types; even adoption involves more low-skill technology products and processes.

STI learning is a series of organization's actions during the production process; it is the transfer and application of scientific knowledge in order to adapt to changes in the environment and build sustainable competitive advantage. STI learning is associated with scientific knowledge and R&D activities. It is the learning that is built from know-why experiences which generate the knowledge necessary for firms to innovate radically. The STI learning process largely originates from universities and public R&D institutions (also called public technology intermediaries), although it can also come from firms. The transfer of this knowledge is not an automatic process, requiring carefully crafted policies and firms and farms that are proactively looking for avenues for innovation. Hence STI learning processes are more prevalent in mature systems of innovation where there is high-tech production. However, DUI is equally important for these systems, as evidence shows that most firms in developed/industrialized countries also innovate without the use of R&D as a major source. But this is not to say that R&D is not important at all in the DUI mode of innovation; to the contrary R&D is normally used in assisting the learning-based innovation, especially when the degree of novelty is appreciable.

In terms of cost associated with these learning processes, DUI learning is a costless or low-cost by-product of doing-based routine activities, while learning by searching and exploring requires mobilization of resources, both human and non-human (Bångens, 1993). However, according to Bångens, although doing-based learning is useful in innovative activities, mastery of technology and innovation of higher degree of novelty cannot be achieved by doing-based learning alone. Instead, explicit policies and investments in innovation capabilities' building become a necessary condition for further progress. The challenge, however, is that there is no short cut in this process—innovation is path-dependent in the sense that what you are capable of doing today to a large extent depends on what you did yesterday. In this regard carefully crafted innovation policies are required to enable countries to move into innovation of higher degrees of novelty from where they are currently – basically moving up from their current DUI innovation mode. The more countries, sectors and firms move towards high tech through DUI, the more they will increasingly also require STI learning. In some sectors, including most of high-tech sectors such as pharmaceuticals and IT, the gap between DUI learning and STI learning is blurred. Under such circumstances, the policies that encourage both models while ensuring that STI learning mode is directed towards complementing DUI learning would have more impacts. For this reason, while enhancing their budgets for supporting R&D activities, governments are also urged to facilitate the interactions and knowledge exchange opportunities between firms and their suppliers and customers to intensify the DUI mode of learning and innovation.

Further readings suggested (on this topic, for those interested)

Chen, J. (2010). An empirical study on the relationship between the STI/DUI Learning and technological innovation performance in Chinese industries, the International Schumpeter Society Conference. Aalborg University.

Lundvall, B.A. (ed). (2010). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Anthem Press.

Lundvall, B.A. and Borras, S. (2005). 'Science, Technology, and Innovation Policy'. In Fagerberg, J., Mowery, D.C., Nelson, R.R. (Eds.), *The Oxford Handbook of Innovation*. Oxford: Oxford University Press. pp. 599–631.

Cirera, Xavier, and Maloney, William F. (2017). The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up. Overview booklet. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IG

1.4 Unit Exercise

(These sets of questions can be used for either a group or individual-based exercise, although generally it is preferable to use in a group setting to stimulate ideas and informed discussions. When done in groups, each team, of 4 to 6 persons answers the following questions, then after 15-20 minutes of discussing and putting together their answers, each group can present their answers to the big workshop group, in 5-10 minutes each. If the number of workshop attendants is small, then perhaps each individual can answer the questions individually.)

1. Given your experience in working with the SGCs (or a similar institutions), please provide critique or support to the conceptual layout (of this unit) that was just presented to you.
2. Between DUI and STI modes of learning and innovation, which one do you think is more appropriate for your country and sectors? Please explain.
3. Relate your current thinking with the existing STI policy/policies in your country. Do you think there is anything that needs to be changed? What is it?
4. Please discuss the current proposals of African countries to commit 1% of GDP to R&D. Do you think it should be more or less, and why? Besides that, what other things do you think should be emphasized in regard to R&D? (e.g. How can the R&D be made to have impact on the lives of the people in Africa?)

UNIT 2: HISTORICAL ACCOUNT OF INNOVATION MODELS AND IMPLICATIONS FOR POLICYMAKING

Unit Objectives

The main objective of this unit is to equip the participants with a general understanding of the main concepts related to the historical evolution of conceptualizing innovation as a systemic process and its implications to policymaking.

Unit Outcomes

At the end of this unit, participants should be able to link innovation theory to innovation policymaking and practice.

Unit Topics to be covered

The topics covered in this unit include; a historical account of the innovation models, the linkages between innovation theory, policy and practice, the basic models of innovation – from linear model of push and pull types, to systems of innovation, and the relevance of innovation models to the African context.

2.1 The Linkages Between Theory, Policy and Practice of Innovation

In a globalized economy, with turbulent political, social and economic environment, investors are confronted with challenging questions, for example whether they should start a new business, invest in new machinery or technologies, or spend more money on R&D. Similarly, in the world of dynamic change, complexity, risk, and uncertainty, innovative entrepreneurs in the developing and emerging economies face the pressure to make business decisions. Such decisions should account for whether, when, and how to develop, produce, and commercialize new products, new services, new technologies, and new models to ensure the best possible results financially, socially, and environmentally (Carayannis and Dubina, 2014). Such decisions are even more challenging for poorer countries; and to a large extent will only succeed with a helping hand of governments in terms of policies.

At the same time, there are policymakers who often are not at all certain about which policy options could be best in directing innovation efforts towards maximization of social welfare, meeting environmental benefits or accelerating economic growth among other priorities. Policymakers are compelled to choose the best possible strategies to create, implement and evaluate an array of such policy alternatives. They have to set priorities and incentives, which will stimulate and accelerate socio-economic development through innovation-focused and innovation-driven behavior of economic agents and stakeholders. Indeed, the state politics and interventions have played a great role in shaping and controlling the practice of innovation and innovation policy, informed by theories emanating from empirical evidence in the past century. Following few paragraphs provide a historical account of innovation studies and theoretical developments.

2.2 A Historical Development of Innovation Theory and Innovation Policy Making

Innovation theory covers, among other domains, the basic definition of innovation and other related concepts, the conceptualization of innovation indicators, models of innovation and the complex theoretical explanations of the innovation process and its governance. Since other units of this module have already defined some of these concepts, we will go straight to the basic models of innovation, in order to gain insights on how the theory shapes the policy and practice of innovation globally and within the individual economies.

Innovation models are the mental models designed to serve the description and sometimes prescription of the innovation process and its systemic nature, in order to facilitate its management and governance. The models serve a number of purposes including:

- Facilitate holistic thinking about innovation rather than partial conceptualizations, including considerations of innovation as a linear process, only breakthrough, only by one firm or only about tangible products;
- Guide the management of innovation and formulation of innovation policies;
- Help in networks and competencies building; and
- Assist in understanding and mitigating the negative impacts of innovations especially the radical and disruptive ones.

Joseph Schumpeter (1883-1950) is one of the earliest economists who studied the nature of innovation. Initial Schumpeterian ideas revealed that small entrepreneurs who are flexible and less bureaucratic bring innovation; his later studies also acknowledge the role of large firms as good sources of innovations, as they take advantage of their monopolistic powers. Scholars such as Christopher Freeman, Roy Rothwell, Bengt-Ake Lundvall, Richard Nelson and Charles Edquist, carried out some more extended empirical studies of innovation by considering innovation as a complex process involving various elements and stages. Based on the efforts of these scholars, several models have been devised on the nature and sources ofinnovation. Rothwell (1994) for example tabulated a five-generation model, later updated with an addition of the sixth generation. The Rothwell's model was widely adopted by scholars, including researchers at the Science Policy Research Unit (SPRU) University of Sussex (Tidd, 2006). By adopting the work of Godin (2009) we will summarize the main conceptual frameworks used in science policy into three main generations:

1. The first generation which focuses on the linear model of innovation;
2. The second generation on the role of industrial competitiveness within firms; and
3. The third generation, which covers National Systems of innovation.

Let us discuss the main assumptions and features for each of these models.

2.3 The First Generation: The Linear Model of Innovation (1945-1975)

As a linear process, innovation is conceptualized through the science-push approach and the market demand-pull approach. Under science-push, innovation is regarded as a product or application of science. The model operated in a basic machine model in a linear fashion where inputting human and financial resources into R&D before the associated manufacturing and processing work generate innovations, which are assumed to reach the market automatically. The model is linked with a famous paper by an American engineer Vannevar Bush titled "Science: The endless frontier (1945)". The endless frontier urged the US government to inject more funds and improve the autonomy of universities to engage in R&D activities in order to stimulate innovation. Bush's paper was informed by the success of the military science, especially the Manhattan Project (responsible for the atomic bomb) that provided evidence that scientific activities can be focused to achieve predetermined societal goals. Because of the conviction that science brings benefits to society, the need to manage scientific activities induced the efforts to collect and interpret scientific data. The OECD has championed the development of methodological tools for collecting national statistics on R&D. The following figure illustrates the logical flow of the innovation process under the linear science push model.

Basic Science ⟶ Engineering ⟶ Manufacturing ⟶ Marketing/Sales

Among the caveats for the science-push, linear model is the need to ensure that public research funding does not crowd-out the private investments. In some cases, academics in the public domain are claimed to lobby for their improved access to public resources in the name of "science, the endless frontier". However, it was soon discovered that science alone cannot be an endless frontier; something else is needed. For instance, in the 1950s, the director of the US Bureau of Budget, Harold Smith, disappointed by Bush's paper, suggested that Vannevar Bush's Science: The Endless Frontier, be renamed Science: The Endless Expenditure (Godin and Lane, N.D). To correct for the observed limitations with the linear model, suggestions have been offered, including these:

- To maintain the socially optimal public research funding program in a resource constrained society/country (what would be the amount of public investment necessary for arriving at the "optimal" allocation of resources?)
- To focus the academic research in the public domain towards the areas which are proven less viable to the private sector.
- Subsidization schemes or other instruments that would enhance private sector's research efforts beyond what they would normally do.
- Reinforcement of the intellectual property regime to ensure that private innovators are able to appropriate the outcomes of their investments.

Despite widespread criticism, the linear science-push model is still applicable in certain instances, and still dominates innovation policy thinking in many countries – inappropriately though.

That said, there have been some successful mission-oriented innovations that emerged from focus on the linear model including the United States' DARPA project that contributed to the creation of the internet. Similarly, the history of the American tech giant firm namely Google is among innovations that accidentally emerged out of the public research funding as explained in Box 1.

Box 1: Publicly Funded Research and the Origin of Google

Google has its origins in a research project funded by the National Science Foundation at Stanford University. The project was part of NSF's digital library initiative, designed to improve the science of large-scale information retrieval and storage, awarded to two Stanford professors namely Hector Garcia-Molina and Terry Winograd. The two founders of Google Sergey Brin and Larry Page were recruited as PhD students who joined the two professors in 1994 and 1995. Founding a company was not the primary goal of Page and Brin, nor was it an explicit goal of the NSF while funding their work in the first place. Through financial support by Andy Bechtolsheim, the angel investor from Sun Microsystems, the two researchers applied their research outputs to form their company in 1998 (Owen, 2017).

Aside from the accidental success stories like the Google one, performance in sectors such as pharmaceutical and biotechnology are still dependent – to a large extent – on costly and uncertain basic research efforts for which the private sector lacks incentives to invest in. This is the reason it is still advisable to governments to put more money in basic research. Moreover, the success of applied research very much depends on adequate and high-quality basic research as the line between basic and applied research is blurred. In addition, contemporary social and environmental challenges have further amplified the need for the governments to finance mission oriented basic research aimed at targeting such challenges (Mazzucato, 2018).

An equally contested linear model of innovation is the demand-pull. The model operates in a similar linear logic to the science-push, but in a rather reverse order in terms of the trigger for innovation. The model acknowledges the market demand as a key driver for innovations—it is believed that market demand (existing or potential) triggers scientific research and guides it towards fulfillment of the market needs. The demand-pull model evolved at the time of economic stagnation and recession, the rise in competition and geographical diversification of market demands. The model was especially given impetus by findings of a study by Schmoockler (1972) which revealed that patents followed rather than leading the changes in market demands. Pictorial representation of the demand-pull model is as follows:

Demand ⟶ R&D and Engineering ⟶ Manufacturing ⟶ Sales

However, just like the science push model, the demand-pull model was also criticized, and there are at least two key arguments in the critique to this model; first, the market/demand-pull model is only capable of identifying incremental innovations derived from the existing technologies/products in the market, rather than radical/discontinuous ones. Secondly, the model's assumptions are based on neo-classical economic thinking that markets are characterized by perfect competition and symmetric information. In other words, the leading role of the demand-pull is that consumers behave rationally in the market based on the perfect information they have on potential innovations, and that firms/producers/innovators have an equal chance of competing perfectly in the market. These assumptions have been challenged by the notion of market failure, which will be discussed in the following paragraphs.

As it was stated earlier, the demand-pull is still a linear model; its major distinction with the science-push model resides on its emphasis on coupling scientific discoveries with industry application and market needs. For scholars like Chris Freeman, the science-push and demand-pull models were rather complimentary in a 'coupling mode', instead of mutually exclusive. Along with the coupling conception, it was widely agreed by scholars towards the end of the 1960s that innovation was more complex to be explained by the linear model itself. To some extent, this influenced the innovator/firm-centered models of innovation, away from emphasis on research institutions (push model) and customers (pull model).

2.4 The Second Generation: The Firm-level Competitiveness (1975-1990)

Transitions from the linear model to second generation of innovation were driven by the complexity of innovation processes, making it hard to be explained by a simple linear model, and acknowledgements of the central role of firms to the process of innovation. In relation to firms, a series of academic studies revealed that firms with strong marketing capabilities but lack R&D, as well as intensive R&D projects within firms, which were de-linked from marketing, did not succeed (Mowery and Rosenberg, 1979). Innovation was then understood in terms of abilities to link the firm-level technological capability to the market demands. The model which was developed by Rosenberg involves a complex chain linked model with feedback loops. The complementarities between demand and supply side notwithstanding, there is a general agreement among scholars and practitioners that innovation very much hinges on demand. For instance, according to Guerzoni, (2007, cited in Diyamett, 2010), at each point in time, optimal investment in innovative activities crucially depends on the demand expressed in terms of market size and buyers' sophistication. Moreover, it is the recognition of a potential market that pushes firms to invest in certain capabilities.

Further empirical research on successful innovative firms revealed the strength of their managerial focus on quality, and horizontal and vertical learning processes from suppliers, customers and competitors. Adaptation and responding to globalized customers are among the key success factors for this generation. Companies like TOYOTA for example, developed cars specific for rural Africa, fuel-efficient cars and enhanced the accessibility of their parts through improved distribution chains. Similarly, the Kenyan firm Safaricom has been ranked as the East Africa's largest mobile telecommunications provider and one of the most innovative companies in sub-Saharan Africa. This is partly attributed to the firms' market introduction of M-Pesa, Africa's first SMS-based money transfer service. While the mobile financial services are now widely applied by many other telecom operators in the region and beyond, the level of innovation by Safaricom justifies the role of firms to the innovation process in Africa similar to TOYOTA and other multinationals.

According to the second generation model of innovation, linkages and alliances of firms and their cumulative knowledge are vital to the success of innovation efforts. Moreover, the model emphasized the role of tacit knowledge and organizational learning in enhancing innovation and improvements of the production and distribution efficiency. The boom of Information Technology (IT) facilitated firm-driven innovations through communication and networking of innovation elements in one hand but also, on the other hand, introduced the computer-aided industrial activities such as machinery control, prototyping, simulation and designing. Because of a networking support from IT, the focus of innovation smoothly shifted from only production to a more interactive process with global chains of customer and supplier relations.

2.5 The Third Generation: National Systems of Innovation (from the 1990s)

The literature on national innovation systems that evolved around 1990, with scholars such as, Freeman (1987), Lundvall (1988, 1992) and Nelson (1988, 1993) among others. The literature was influenced by Schumpeterian and evolutionary perspectives, seeing the system as a result of a long historical process characterized by coevolution between a country's industrial structure and its political system. The thinking later on took a sharper focus on the relationship between the outputs of the innovation system. The shift followed a series of empirical studies led by Freeman (1987) and other scholars, showing that countries do not only differ in terms of economic performance but also with respect to patterns of creating and diffusing innovation and the national institutional frameworks supporting it. Such evidence revealed how successful innovation depends on various factors, such as knowledge, skills, financial resources, demand and so on. These factors are considered to be provided within the nation – hence the term "national" innovation systems.

As described earlier, innovation is systemic, and systems of innovations are the determinants of innovation processes. These include all-important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations. Because these elements are nation specific, a concept of national systems of innovation (NSI) was coined. One of the pioneers of this concept, Lundvall (1992), defines NSI as a system constituted by elements and relationships between those elements, which interact in the production, diffusion, and use of new and economically useful knowledge in a particular nation. An NSI includes three types of elements; components, the relationships/linkages existing between those components, and policies and regulations that enhance the interaction between components. Major actors or components in any country include producers (firms or farms), their suppliers, users or buyers, competitors, R&D organizations and universities, public policy organizations, and other relevant organizations such as bureaus of standards. The success of an innovation system therefore depends on nature and capabilities of each of its building components mentioned above, as well as strength of the linkages between such components. Although the major types of actors remain the same in all countries, their relative importance, and the way they interact, are largely different (see for instance Gu, 1999; Edquist, 1997; Lundvall, 1992). An article by Djeflat (2011) identifies the main distinctions between mature innovation systems like that of UK or South Korea with those of developing African countries like Uganda or Burkina Faso. Among the distinguishing factors are the strength of connections between government-industry-academic institutions (the triple helix), availability of human capital, and financial capabilities. To demonstrate the distinction between mature and emerging innovation systems, the table below uses some selected indicators from the Global Innovation Index to compare the national innovation system of Burundi to that of Sweden.

Table 1: Comparing the Innovation Systems of Burundi and Sweden

Item	Score 0-100	
	Burundi	Sweden
Political stability and Safety	21.9	87.3
Ease of resolving insolvency	30.5	79.4
Expenditure on education, % of GDP	5.4	7.7
Gross expenditure on R&D, % GDP	0.1	3.3
ICT Access	21.4	86.9
Easy of getting credit	10.0	55.0
Citable documents H index	0.3	59.5

Source: WIPO, The global innovation index 2017

Innovation systems analysis has typically been focused on national levels, initially through the triple helix relation (universities-government-industries) and later on extended to the multi-helix systems described earlier. With the growth of the international cooperation and regional integrations, the studies on innovations are now being extended towards regional systems of innovation, covering multiple countries such as the East African community or Asia-Pacific Economic Cooperation regions. Similarly, because of the growing variations in dynamics and performance of innovation across sectors, some scholars have shifted their focus on innovation systems at the level of sectors forming the domain of sectoral systems of innovation.[3] For example, one could simply study the agricultural innovation system of a region/country or even more specifically the maize innovation system.

It is also important to acknowledge the embeddedness of the NSIs within the wider global context. Although this has always been the case, the global context is currently becoming ever more important because of the process of globalization that is now taking place. This fact has led some scholars of technological innovation to argue whether it is appropriate to refer to "National Systems" under the current environment of globalization. The point often made is that the literature on innovation systems (IS) has underemphasized the crucial impact of international information exchange and collaboration on the generation and diffusion of knowledge and innovation through different international channels (Pietrobelli et al., 2008); notwithstanding, however, that local context including country specific policies, rules and regulations will always remain very important factors for a country to be a competent player globally, thus validating the usefulness of the concept of NSI.

2.6 The Transformative Innovation Policy Framework

Under the NSI model, value creation from innovation stimulates economic growth and development of nations. The concentration of innovation theory and policies on economics has emerged from the definition of innovation with its emphasis on value creation and market performances of inventions. This view has attracted criticism

[3] See for instance Malerba (2002; 2004) who is the originator of the concept of sectoral systems, for further information.

over its narrow focus on economic interests and its underlying undesirable social and environmental effects, including climate change and inequalities. Such critique has induced an alternative definition of innovation frames and policy directions, namely the 'the transformative innovation policy' framework (see for instance, Scotch and Steinmueller 2018). The framework attempts to redirect the innovation discourse and policymaking more towards meeting social and environmental needs beyond economic growth. There is already an emphasis within the transformative innovation policy framework that, instead of imitating the growth-centered model of the global north, the global south needs a shift in its policy direction towards the quality of growth itself. Issues of steady, long-lasting, inclusive and employment generating growth and consideration for the Sustainable Development Goals (SDGs) are advocated along with innovation policymaking in the continent. This new model has triggered debate and discussions within the continent, particularly on the interpretation and consideration for its relevance and importance.

2.7 Co-evolution of Innovation Theory and Policymaking – From Technology Push to Systems of Innovation

Looking at the history of the innovation policy making, one realizes a co-evolution between innovation policies and theories. Generally, the innovation policymaking process has evolved in response to the evolution of concepts and models – models themselves emanating from practice. Starting with the linear model, which was almost automatic- with very little empirical studies preceding it. It emerged as a result of the success of the military science, especially the atomic bomb. The success of the military science provided the evidence that scientific research can fruitfully be focused to successfully achieve pre-determined societal goals. It became the beginning of the early STI policymaking, with major emphasis on investment in science (R&D) to achieve predetermined social and economic goals in countries. As time went by, it was soon realized that such investments are not producing the expected impacts on social and economic development, and as a result this triggered more empirical investigation on how innovation actually takes place in a given social and economic settings. Such empirical studies led to subsequent proposals of models, where the national systems of innovation (NSI) became dominant, and largely put into use to design innovation polices by different countries. In Tanzania for example, the Ministry of Communication, Science and Technology in collaboration with UNESCO has recently conducted a study on the state of the Tanzanian innovation system. Among the proposals from the study's report were improvements of the state agencies dealing with innovation, improved R&D financing and connecting this to use, and formulation of the new STI policy to improve the existing S&T policy of 1996. The recommended policy review process is still ongoing. In Kenya, the formulation of the ST&I policy in 2013 transformed the innovation system. New institutions were formed, including The National Research Fund, Kenya Innovation Agency and The National Commission for Science, Technology and Innovation (NaCOSTI) which succeeded the National Council for Science and Technology.

The current National innovation policies and strategies, which are derived from the NSI conceptualization, are largely structured in a manner that facilitates innovation within firms, with emphasis on the five policy areas;

1. **Knowledge:** Produced by the firm and complimented by public R&D organizations including universities. Alternatively, knowledge may be produced through government-facilitated schemes that promote interaction between firms and other actors in the system.
2. **Skills:** Academic skills, technical skills, managerial skills and interpersonal skills, such as work ethics and teamwork spirit, are vital for successful innovations. Skills, which range from specialized to the more general, are essential for firms' abilities to generate technological dynamics. The level of skills in an innovation system depends on the strength of a country's education system, including academic, vocational and DUI environments, and lifelong learning.
3. **Demand:** Without demand for new, innovative solutions, innovative firms get nowhere; the demand for innovative products depends on the size and purchasing power in markets and their behavioral responses (adoption rate) towards innovations. The role of governments in stimulating demand includes alteration of standards and regulations and using public procurement proactively to foster innovation (Edler and Georghiou, 2007; Edquist and Zabala, 2012).
4. **Finance:** Financial support is a necessity for innovation to persevere. Some innovative initiatives, particularly from small firms, entrepreneurs, etc., or those characterized by high levels of uncertainty, are constrained with difficulties in raising the necessary finance in ordinary financial markets, and in such cases the public sector's intervention is needed through its incentives and financial instruments including subsidies, awards, guarantees, loans, grants or venture capital funds.
5. **Institutions:** Institutions refer to the "rules of the game" that influence the actions and behaviors of firms and other players in the innovation system. They range from policies, laws and regulations—for example IPRs, requirements for setting up or closing down businesses, regulations regarding hiring or firing personnel, the prevalence of corruption and laws and procedures for handling of commercial disputes.

2.8 Innovation Models, Policy Process and Indicators

In the previous section we tried to establish a relationship between the policymaking process and innovation models: we have seen that, during the earlier days of the linear model of science-push and demand-pull, STI policies in most countries were dominated by investments in science and scientific research with expectation that this will automatically translate into new products and processes, and by implication social and economic progress. We have also seen that, further research on the innovation process, i.e. how exactly innovation takes place and achieved in a given social and economic setting, led to the continuous modification of the models – leading to the current NSI framework, and new policy directions that take into account the systemic nature of innovation. It is important to note that, along with these changes is also a modification of the STI indicators systems, **which are indispensable tools for policymaking in the sense that they provide evidence for policy.**

In line with the early linear model of innovation and policy making, the early indicators systems for innovation were R&D intensity, i.e. R&D expenditures as a proportion of gross domestic product (GDP), and formal R&D indicators manual development and surveys predated the innovation ones by almost 30 years—while the first systematic innovation survey for the OECD countries was carried out in 1993, the one for the R&D was in 1963 (Godin, N.D). A move towards innovation manuals and surveys – in addition to original R&D surveys – was a result of more studies on the innovation process, and realization that innovation does not seem to solely arise from investments in science – at least not in a linear fashion as was hitherto believed. In relation to this an OECD *ad hoc* group on science, technology and competitiveness, for instance, had the following to say: "Innovation cannot be reduced to, nor does it solely arise from R&D", and admitted that "it is probably quite as erroneous and misleading for appropriate and adequate policymaking for technology and competitiveness to equate R&D with innovative capacity (OECD, 1984, pg 40, cited in Godin, N.D).

As we write this handbook today, there are already several editions of the Frascati Manual and four of the Oslo Manual, where the latest came out in 2018. These revisions were prompted by additional information about the innovation process, gained through various innovation related studies and surveys, which in turn were informed by existing innovation models/theories. Unfortunately, such studies and surveys were to a large extent limited to the context of more developed countries, bringing forth the popular argument that such indicators cannot be appropriate for policymaking and systems monitoring in an African environment. This is from the fact that innovation processes are context specific – i.e. depending on the social, economic, political and cultural environment of a given country or region. Many scholars of innovation – especially on innovation systems – have consistently argued for this. According to Edquist (1997) and Gu (1999), for instance, the relative importance of the innovation system actors and the way they relate to each other very much depend on the socio-economic context of a given country. This means that for African countries to come up with proper innovation models, policies and indicators they have to study their contexts, and make adjustments to the currently existing innovation models. Otherwise mere adoption of a given systems of indicators without understanding how they came into being and their relationships with how innovation takes places in a particular context (innovation model) is really not useful for further improvement of the appropriate indicators systems in an African context

Further readings suggested

Tidd, J. (2006). *A review of Innovation Models*, Imperial College London.

Djeflat, A. (2011). 'Innovation Systems (EIS) and Take-off: Evidence from the North African Countries.' *African Journal of Science, Technology, Innovation and Development* Vol.3, No.2, 2011 pp.16–45

Muchie, M. Lundal B. A, Gammeltoft, P (eds). (2003). *Putting Africa First: The Making of African Innovation Systems*. Aalborg University Press

2.9 Unit Exercise: Measuring Research and Innovation in Africa

(This exercise can be done either in a group or individually, although generally it is preferable to use it in a group setting to stimulate ideas and informed discussions. When done in groups, each team, of 4 to 6 persons reads the case below and answers the following questions, then after 20-25 minutes of putting together their answers, each group can present their answers to the big workshop group, in 10 minutes. If the number of workshop attendants is small, then perhaps everyone can do this exercise individually.)

African countries are aspiring to build their STI systems to promote economic growth, reduce poverty and increase their global competitiveness. In an effort to improve the policymaking field – just like more developed countries – African countries have started measuring their innovation and R&D activities. A good example is the measurement drawn from the Frascati and Oslo Manuals respectively. Efforts have been made (particularly under the NEPAD's African Science, Technology and Innovation Indicators (ASTII) program) to generate STI indicators and use them for policymaking in the continent. Through this program two sets of the African Innovation Outlooks (AIO), involving about 35 African countries, were generated (AIO, 2010 and 2014). As a result, evidence has revealed the benefits of defining, generating and utilization STI indicators as key ingredients in informing operations of the STI sub-system itself and its relationship with the wider social and economic systems. Basing on these two model surveys funded by Sida (Swedish International Development Agency), some countries have continued financing similar surveys in their countries; one such country is Rwanda.

The above benefits of R&D and innovation surveys notwithstanding, there is an increased criticism that, because such manuals were developed using empirical evidence emanating from different contexts other then Africa, their use for policymaking in Africa must be done with a lot of care; and already there is an ongoing debate among African scholars and policymakers on the need of tailoring the Oslo and Frascati manuals to fit the African social and economic environment.

1. How best can your country engage in improving the conceptualization and adoption of the STI indicators to fit its local context? (For example, by accommodating informal R&D activities).
2. What are the strategies used by your country to undertake regular M&E (monitoring and evaluation) on its innovation system, including the generation of the STI indicators?
3. How have the previous STI indicators shaped local debates on innovation policy formation and influenced the practice in your country?
4. What is your country's position on the African target (From Lagos Plan of Action) of committing 1% of the National GDP on Gross domestic Expenditure on R&D (GERD)?

UNIT 3: THE INNOVATION POLICY PROCESS

Unit objectives
To foster better understanding of the STI policymaking process among the SGCs and STI policymakers, more generally.

Unit expected outcome
It is expected that this unit will contribute towards better STI policymaking in Africa, especially in linking scientific research to the activities of productive sectors.

Unit topics to be covered
What is public policy, and specifically what is STI policy; the science policy; the technology policy; the four stages of the policy process: agenda setting, policy formulation and adoption, policy implementation, and policy monitoring and evaluation; policy instruments and policy mixes.

3.1 What is STI Public Policy and Why is it Important?

We differentiate between private and public policies. The policies that individuals and businesses adopt are **private policies**; for instance, a business company's policy on how it produces goods and markets them is a private policy. **Public policies** are those that governments adopt to address problems in a country or society. This model deals with public policies only. Generally, a public policy is a course of action taken by the government to address a certain problem in society; it is a deliberate system of principles to guide decisions and achieve rational outcomes. People typically involved in public policymaking and decisions are the president of the country, ministers and commissioners – especially the one responsible for the policy issue – and their advisors (who can be individuals or organizations – e.g. councils and commissions – located all over the state apparatus and sometimes outside of it). In the case a policy requires a regulatory instrument in its implementation, the legislative branch of the state (e.g. parliament) is also involved; so, they too are counted as policymakers (and they too have advisors).

STI policies are principles that guide decisions in STI to achieve predetermined social, economic and environmental objectives. More specifically – following the systemic nature of innovation – STI policy can be understood as government actions aimed at influencing decisions of the major actors in the innovation system, namely producers (innovators), customers of innovative products, input suppliers, knowledge organizations, financial institutions, the government and other agents to create, disseminate and use knowledge to innovate for social and economic benefits of society. Being a cross-cutting thing, STI policy ought to actively involve many decision makers (e.g. a number of ministers).

STI policies are important – especially for Africa, because of the inherent characteristics of poor countries, market mechanisms cannot allocate adequate resources to the generation, dissemination and use of knowledge for the production of goods and services. To the contrary, in richer countries, where innovation systems are much stronger, to a large extent market can allocate resources to the production, dissemination and use of knowledge in social and economic activities. For instance, in such countries, firms – through market mechanisms – proactively search for knowledge for innovation from universities. To the contrary, in developing countries, such as those in Africa, connection between universities and the private sector is a major challenge. To enable such linkages to work, government has to intervene through policies. In this regard, policies are tools used by governments to correct market or system failures in the allocation of resources in the market economy. For instance, while many African governments seems to have appreciated the systemic nature of innovation, and in blueprints are gearing their policies towards this direction, when it comes to implementation the focus is still largely on the linear model, i.e. on investments in science and research. However, for such research to have impact on the lives of the people, African governments need to equally focus their STI policies on linking research to use, and generally focus on strengthening their national systems of innovation.

STI policy, although usually taken to be one policy, can actually involve a number of STI related policies such as science policies, technology policies and innovation policies. Below, we briefly define these:

Science policies are rooted in public support for scientific activities. They include the promotion of scientific research in a country. Key drivers for science policy include national security, prestige, cultural values and – especially nowadays – economic growth and competition. In most cases, science policies influence the allocation of public resources towards scientific research (both basic and applied research) and related activities at universities and public research labs.

Technology policies, on the other hand, are normally driven by the development of science-based technologies and their relation to the industrial competitiveness of nations. Technology policies, in modern states, are mostly concerned with strategic technologies and sectors, such as biotechnology, ICTs, energy technologies, etc. However as earlier explained, technology outputs are useful, at the national level, if they contribute to socioeconomic goals, and also as long as it keeps improving. Certain technologies may serve economic growth for a while, but without dynamic improvement they run the risk of becoming irrelevant to local and international developments. This brings us to the concept of innovation. Once some technologies (or technology outputs) are strategically chosen for investment, they often need to continuously adapt and upgrade in response to developments in the field—i.e. innovate. This is the reason that many countries nowadays rarely talk of technology policies exclusively, but innovation policies.

Innovation policies can be defined broadly as all policies that have an impact on innovation, or more narrowly as policies (or policy instruments) created with the intent to affect innovation. They focus on the main actors in the innovation process and their interactive linkages and learning. Innovation policies emphasize strengthening the individual components of an innovation system while reinforcing their interactive linking and learning. Science and technology policies can be assumed to be included in innovation policies, but in addition to the development and commercialization of technologies from scientific undertakings innovation policies are also concerned with the diverse (and adverse) impacts of technologies – including issues of consumer protection, environmental impacts and human ethics in relation to use of new technologies. Innovation policies also deal with incremental innovations that do not necessarily emanate from scientific research but are achieved through learning by doing. Innovation policies also include non-technological aspects such as improvements of organizational and marketing systems.

3.2 The Policy Process

There are normally 4 stages in the policymaking process: agenda setting and problem definition, policy formulation and adoption, policy implementation, and finally monitoring evaluation and learning. While these stages are not independent of each other in practice, but cyclic as indicated in Figure 1, for the purpose of explaining the process, we distinguish the four stages as explained below:

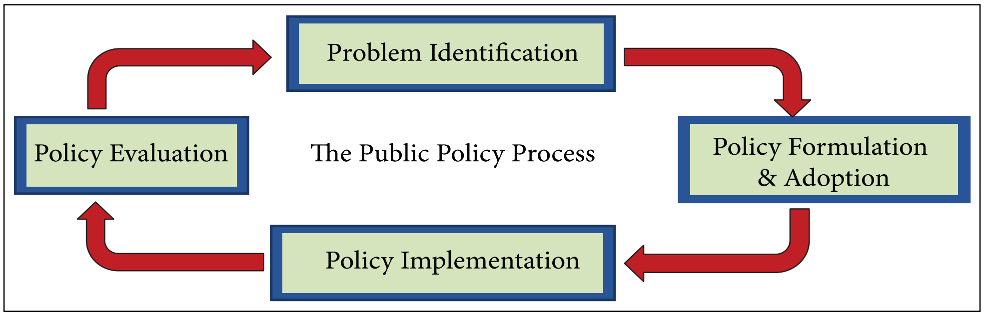

Fig.2: The Cyclic Nature of the Policy Process

3.2.1 Agenda setting and problem definition

Before a policy can be created, a problem must exist that is called to the attention of the government: there must be a serious social/economic/environmental problem that needs to be solved. While finally, when the agenda has been passed, responsibility of further policymaking processes lies in the hands of the government. The agenda and problem definition can come from anybody or group in society—whether government, private or the civil society.

One example of an agenda setting arising outside the government is what CRES – a think tank – in Senegal did for anti-smoking regulation that the region was battling with for several years: CRES carried out an action research on regional harmonization of taxation of tobacco products to reduce its consumption. The research outcome and its popularization finally resulted in tangible policy changes at both national and regional levels. At the regional level the research outcome led to the adoption of a new directive on taxation of tobacco products by ECOWAS Heads of State in December 2017 (Founty, et al, 2019). This is an example of initial action taken by an independent think tank, but governments themselves or its agency, such as an SGC, can set the agenda on an important STI issue, by bringing the issue – with convincing evidence – to the attention of decision makers in the government. The process in which the policy issue or problem is brought to the attention of the decision makers within the government can be different between the government and non-government actors, but it is setting agenda any way – one need to convince the final authority in the policymaking process that indeed there is a problem or issue that require policy attention, and statistics and indicators are very important here.[4] For instance, one of the very visible problems, also a major concern of top decision makers in Africa, is unemployment, where job creation through value-addition to natural resources is critical. One important input in this process is STI capabilities. However, one needs evidence to convince the decision makers that indeed there is a strong relationship between unemployment and STI capabilities of countries. Once this is agreed upon, the next important question to ask is: do countries have adequate capabilities in STI? Do the STI systems perform optimally? For sure we know that the answer to these questions is no. It then becomes the problem to be targeted for the STI policy, with the objective of improving the performance of the STI system and build capabilities of individual actors – more generally or in selected sub-systems that have greatest impact on employment.

The above notwithstanding, agenda setting and influencing policies are not easy or straight forward processes. According to Kingdon (1995) the success of any policy process depends on coupling between three streams of otherwise independent streams: 1) the problem stream, 2) the policy stream, and 3) the politics stream.

The problem stream is the agenda setting stage as defined above; the policy stream is the proposed policy options to address the identified problem; and the politics stream regards the political will and commitment to address the problem. According to Kingdon, the three streams develop independently from each other. They are for the most part unrelated. For instance, a problem can be identified correctly but wrong solutions proposed; in such instances, even if there is a political will and a policy implemented, the policy will not achieve the desired outcome. In another instance, the right policy options to address the problem may have been identified but if there is no political will and commitment it means that the policy will not be implemented. To the contrary, when there is coupling among the three streams (as shown in figure 3 below) a window of opportunity for the design and implementation of policy (with correct policy instruments) emerges. The window of opportunity is where the three spheres intercept.

Policy windows mostly open occasionally and might not stay open for very long. Thus, actors who promote a specific problem and its solution, whom Kingdon described as *policy entrepreneurs*, must act quickly, before the opportunity passes, or else they will have to wait until the next chance comes along. Policy entrepreneurs, like economic entrepreneurs, will do anything to make sure that their ideas are put on the agenda of politicians. Policy entrepreneurs can come from both public and private organizations, and even individuals in their own right. Basically, any organization or any individual in society – e.g. civil servants, politicians, researchers – can be policy entrepreneurs for particular issues (Kingdon, 1995; Guldbrandsson and Fossum, 2009)

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[4] In the SGCI (Science Granting Councils Initiative), of which this activity is part of, theme 2, led by AUDA-NEPAD, focuses on STI indicators.

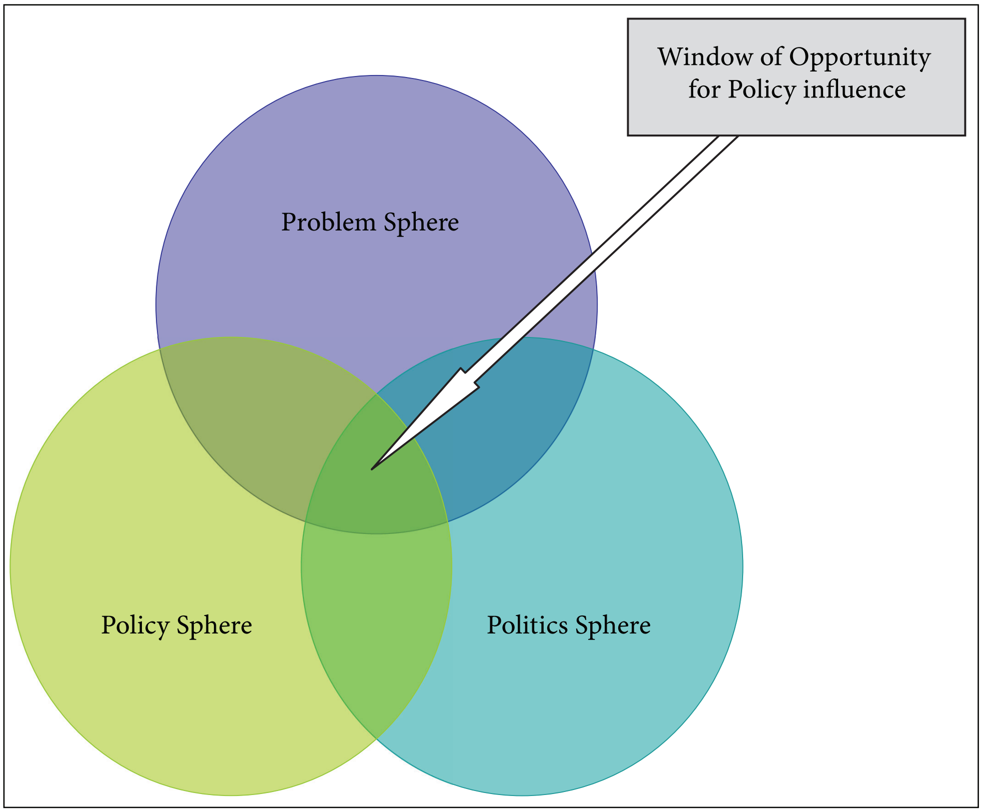

Fig 3: The Coupling of 3 Sphere of the Policy Process

According to Kingdon, (1995) policy entrepreneurs are people endowed with the following resources:

i) *Claim to a hearing*, which means that an actor has an ability to speak for others, hold a decision-making position or possesses requisite expertise;

ii) *Political connections and negotiating skills*, implying a combination of technical expertise and political know-how; and

iii) *Persistence*, and Kingdon labeled this resource as the most important. This means that policy entrepreneurs promote their ideas in all ways and in several fora and are willing to invest large resources in order to promote solutions to existing policy problems.

Looking at Box 2, with the STIPRO case, one realizes a very close connection between the case and Kingdon's theory. This case, like kingdom theory, indicates that there are neither a short cuts nor formal formula in setting successful policy agenda and influencing implementation; it requires, unshakable vision, commitment and patience to try many possible alternatives to arrive at goals. It is something that can be done by anybody in the country, be it from the government or from outside it (although of course major strategies differ between government and non-government actors). But generally, the relevant literature points to the importance of good governance and democracy for such policy entrepreneurs to thrive. See for instance Krane and Gari (2003), who argue that democracy and public policy are intertwined because the organization of authority in a nation affects the design and implementation of government activity. They further argue that fundamental to democracy is the notion that citizens possess the ability and means to shape decisions made by public officials.

Box 2: Example: The Case of STIPRO as STI Policy Entrepreneurs

In 2007 STIPRO, then known as ATPS-Tanzania, published a newspaper article in the national newspaper 'Majira, on the 30th of August.

The article was an effort to draw the attention of the Tanzanian public, including that of the government, to a need to review the national systems of innovation by pointing out to some statistics that indicate all is not well. The ideas contained in the newspaper were originally meant for a local TV appearance, but efforts to get a space in the appropriate local TV channels at that particular time seemed to be close to impossible. STIPRO therefore decided to change the approach of reaching out to the public and decided to write a newspaper article instead. This article had a picture of the then president of the United Republic of Tanzania, the then minister responsible for science and technology, and the author of the Article from STIPRO.

STIPRO did not just stop at publishing this article, but influenced its readership among those who mattered, and followed up on the possible outcomes. A year down the road it was realized that the government had indeed started a national project on the review of the national systems of innovation through support from UNESCO. Here come the challenges of attribution – especially when it comes to policy influence – normally there would be contributions from different sources and actors, including the government itself, and to say for sure that a particular source has greatest contribution is very difficult; unless there is an open acknowledgement. Notwithstanding, a number of indicators, including the fact that the article was used as one of the references during the initial work of the review by the task force, showed the extent of STIPRO's contribution in the initiation of the project. The article also mentioned the work of UNESCO in the review of national systems of innovation of other countries.

Three years further down the road, STIPRO realized – through informal networks – that the project is having some challenges, threatening its successful completion. STIPRO then sought alternative ways to contribute to the rescue of the project. Consequently, STIPRO decided to plan for the organization of a national seminar on innovation and innovation policies, where renowned authorities in innovation worldwide were invited. Invited were also presentations on the experiences in the review of the national systems of innovation from other African countries—Nigeria and South Africa accepted the invitation. This seminar gave STIPRO an opportunity to officially and formerly approach the government, informing them about the seminar and there will be some presentations from countries with experiences in the review of national innovation systems, and requesting the Tanzania to also present its case—a proposal that was accepted by the government. The seminar finally took place on March 23rd, 2012. The outcome was the reformation of the task force, where STIPRO was officially represented in the task force. The review was successfully completed and was used to draft the new STI policy for Tanzania, which is still in process.

3.2.2 Policy formulation and adoption

Once the agenda has been set and agreed on, next is coming up with approaches to solving identified policy problems, which goes along with statement of the policy objective(s) – desirable outcome(s) once the problem has been solved. Clearly stating the policy objectives is extremely important, because it is against these the impact of policy will finally be evaluated. Remember that some policy proposals must have already been proposed during agenda setting by policy entrepreneurs. This stage involves several actors, including those that will finally be responsible for policy implementation and those that will be affected by the policy.

In most cases there will be several approaches to solving an existing STI problem. The process includes analysis and identification of the best solution—i.e. solving the problem in the most efficient and feasible way possible. According to Hayes (2014) there are two aspects to policy formulation: the **analytical** and the **political**. First, effective policy alternatives, presumably based on sound analysis and evidence, must be conceived and clearly articulated. Second, a political choice among these alternatives must be made: the policy must be authorized through a political process, such as legislation or regulation. Both phases, analysis and authorization, comprise policy formulation.

The role of the policy analyst is extremely important here – to identify concrete causes of the problem and propose alternative solutions. Let us have a hypothetical example of an innovation problem, where national companies are not engaging in innovations of higher degrees of novelty. There could be a number of causes to this problem: companies could be having ideas and capabilities to innovate but lack venture capital to implement an innovative idea; or the companies could have capital but are poor in business analysis/planning, and therefore difficult to recognize an innovative opportunity; or it could be that the companies lack requisite skills and knowledge to implement an innovative idea. Each of the causes of the problem has a unique solution: lack of venture capital can be addressed by financial instruments such as direct funding, soft loans, etc. The problem of weak business skills can be addressed through provision of training courses, especially on technology and innovation management. Inadequate innovation knowledge and skills inputs can be solved by linking companies with knowledge generating institutions, such as R&D institutions (or public technology intermediaries) and/or building the absorptive capacity of the employees of companies. This means, to be able to propose a correct solution to an innovation problem, a policy analyst has to understand the causes of the problem; and this is the basis of an evidence-informed policymaking.

Evidence-informed policymaking is attractive, not only because it is convincing in the eyes of the decision makers, but because once implemented it has a greater chance of addressing a policy problem/resolving a policy issue correctly. This is in line with Borass and Edquist's (2013) argument that political support and the effectiveness of policy instruments are very important aspects of the success of any innovation policy, which is in line with Kingdon's theory on the three streams of the policy process, mentioned earlier.

Important to solutions of policy problems are instruments to be utilized; and for innovation, which is basically systemic, is also the issue of policy mixes. The following few paragraphs are devoted to discussing these two elements:

a) Policy Instruments

A general definition of public policy instruments is "a set of techniques by which governmental authorities wield their power in attempting to ensure support and effect (or prevent) social change" (Vedung 1998, cited in Borass and Edquist, 2013: 5). For the case of innovation, policy instruments have a specific purpose and are unique (Borrás and Edquist, 2012). Their goal is to bring about change (or prevent a situation considered to be appropriate from changing) in a specific way, in a direction that it is believed will stimulate attainment of STI policy objectives. The instruments are unique in that they are selected, designed and implemented with a specific objective in mind, in a specific policy context, at a specific point in time, and in a specific political situation for the government.

Policy instruments are generally in different categories; below we highlight three broad categories as indicated in Borass and Edquist (2013).

1. Regulatory instruments

These can be various, but one example is when patent and university laws are changed in order to allow universities to own patents and to create the necessary organizational arrangements to stimulate the commercialization of knowledge, such as creation of incubators and spin-off companies. Remember also that regulatory instruments can affect innovation in indirect ways; for instance, an environmental regulation forbids a specific polluting chemical substance, or forces a reduction in industrial waste; this induces product innovations or process innovations, because the regulation forces firms to find alternative solutions.

2. Financial incentives instruments

One of the most widely used financial instruments is public support to research organizations, primarily public universities and public research institutions – which are the supply side innovation policy instrument. Others, which are more focused on the innovators themselves, are: tax incentives for R&D performed at firm level and retraining of the works force, innovation grants to SMEs, and support to technology transfer (for instance through support of joint R&D between firms and universities/public R&D institutions, or supporting imports of existing technologies through reduction of import tax). Other financial instruments popularly mentioned in literature include support to venture and seed capital for the commercialization of new technologies. Added to this type of instruments are instruments targeted at stimulating demand for innovation such as public procurement.

3. Soft innovation policy instruments

Soft instruments are characterized by being voluntary and non-coercive. With soft instruments those who are 'governed' are not subjected to obligatory measures, sanctions or direct incentives or disincentives by the government or its public agencies. Instead, soft instruments provide recommendations, make normative appeals or offer voluntary or contractual agreements. Examples are:

i. Dissemination of information about voluntary technical standards at the national and international levels.
ii. Dissemination of information on the importance of public-private partnerships (PPPs).
iii. Campaigns and public communication instruments (for example, diffusion of scientific knowledge by using events like "research days" or TV documentaries).

b) Policy mixes

The innovation process being complex, systemic and a multi-actor field, can rarely be addressed through a single policy instrument: Often, the complexities in innovation induces a multi-faceted barriers to innovation in different forms under different contexts, e.g. in various markets, systems and institutional failures, which eventually call for an intervention through different mixes of policy instruments (see for instance, Borras and Edquist, 2012; Braathen, 2007; and Weber and Rohracher, 2012) for similar arguments. Understood this way, Borras and Edquist 2012, defined instruments mix in the innovation process as a combined set of policy instruments that when put together addresses complexities in innovation processes. In this kind of relationship, instruments interact with each other and create interdependent, positive and self-reinforcing relationships, which are central when it comes to achieving policy objectives. The term 'instruments mix' is somehow similar to 'policy mix', and sometimes the two terminologies are used interchangeably. However, we here differentiate the two: by policy mix we mean completely different policies reinforcing each other, e.g. different sectoral policies. For instance, to be effective, STI policy needs to be in line with most sector policies—e.g. with the industrial, agricultural, education and trade policies. Sometimes a popular terminology used in this is policy coordination. Good example here is trade policies, where some trade related policy instruments such as tariffs have direct bearing on innovation capabilities. They are useful as a protectionist instrument by affording new and infant domestic economic activity a chance to grow and become competitive. Tariffs used for this purpose must have time limitation.[5]

The above notwithstanding, it should be noted that instruments mix should be chosen very carefully, because, while there are several situations where different policy instruments reinforce each other, there can be a number of situations where one or more instruments in the mix adds little to the benefits—only adding to the costs. This therefore calls for an *ex-ante* policy assessment before it is implemented. *Ex-ante* assessment or evaluation is an evaluation carried out before a program or policy is implemented. Its major objective is to gather information and carryout analysis that helps to properly define objectives and that it is possible to meet them; other functions of the *ex-ante* assessment is to ensure that the instruments used in the implementation of policies are cost-effective, and that, later on, a reliable *ex-post* evaluation is possible. *Ex-ante* assessment is mandatory in some countries, e.g. the European Union, before a program is implemented. We wish to also suggest that, let it be mandatory before STI policies are implemented in African countries.

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[5] Time limitation tariffs is important as it compels protected firms to innovate and become competitive so as to avoid the tendency towards permanent infancy – without time limitation, this trade instrument will work against innovation.

Properly weighed out STI policy instruments mixes – including through means such as the ex-ante assessments – are required to balance the supply and demand sides of the innovation process. In most cases, what we are witnessing – especially for Africa – is the use of supply side instruments, such as support to R&D, in isolation to the complementary demand side innovation policy instruments. At best, we see tax exemptions for the importation of some machinery as some form of demand side innovation policy instruments, but again this is used in isolation from the supply side instruments by not connecting imports of existing technologies to the R&D carried out in public institutions, including universities, for the purpose of adapting and improving on these technologies. To the contrary, experience teaches us that most countries moved up the innovation capability ladder by targeting their R&D to the improvement of the imported foreign technology. A good example is Japan, during their catch-up period. So, in principle, support to R&D should go hand in hand with policy instruments that facilitate linkages between industries and research organizations. One example is the instruments that are currently being tested by theme 3 of the SGCI, by providing finance for collaborative projects between the private sector and public research organizations, including universities.

Another very important demand side innovation policy instrument, that can balance the supply side policy instrument of support to R&D, especially when it comes to innovation of higher degrees of novelty, is public procurement. This instrument is very popular in rich countries, e.g. popularly used in directing innovation towards more environmentally and socially friendly technologies. However, STI instrument mixes, if correctly used, should be different for different countries and regions owing to the fact that innovation is context specific, depending on social, economic and political environments of different regions and countries. It is therefore quite difficult, if not impossible, to find 'optimum models' for instrument mixes that cut across all countries and regions; although, unfortunately – especially for poor countries – there is tendency to copy policy instruments that have worked elsewhere. An example is the emphasis on commitment of larger percentages of GDP to R&D for poor countries, with the argument being that developed countries are committing large percentages, so why not us? Such argument may be forgetting that there is a history behind commitment of such large percentages. Such things did not happen overnight, as explained in the DUI and STI modes of innovation. Committing adequate percentages of GDP to R&D is very important for every country, but even more important is linking this to social and economic activities in each context. Of course, such copying is not limited to poor countries, rich countries also do. Often, even in Europe, the mix of policy instruments used has been more the result of a transfer of solutions used in other places than an adequate response to national challenges (Izsák et al., 2013).

Policy instruments should also not be static; they have to be designed, redesigned and adapted to the specific problems encountered by innovation systems over time. Insofar as innovation systems evolve, the functions fulfilled by certain agents change. Moreover, agents are constantly learning, meaning that their responses to the incentives associated with a given instrument can change with time. For example, firms adapt their behaviour to the stimuli that are available, and if they observe that funds are made available each year for private investment in R&D, they may decide to invest less of their own resources. Therefore, the search for the best instrument mix is not a one-off exercise, but an ongoing process that adapts to innovation system dynamics (OECD, 2010).

3.2.3 Policy Implementation

Policy implementation is the third stage of policy process that follows after the policy is formerly endorsed. It is translating policy into actions; normally after it was carefully translated into programs or actions that will be taken to make the policy to have desired impact, or by following a set of process to translate the policy into actions that ensure the achievement of its predetermined objectives. Normally this is accompanied with the commitment of adequate resources – both financial and non-financial. During the policy implementation process various actors, organization, procedures, and techniques work together to put adopted policies into effect in an effort to attain policy or program goals (Essays, UK, 2018).

Policy implementation is the most problematic stage in the policy process. In most cases it can easily go wrong. According to policy implementation experiences, there are important preconditions that must be followed for successful implementation of policies. We extract the following as most important among listed in Duane Herperger (2019):

- Every stage of policy design, especially the choice of instruments, needs to have successful implementation in mind.
- It requires sound leadership, an inclusive approach and sound processes and judicious use of resources.
- Time consideration, costs and resources required.
- Proper planning – i.e. put in place manageable milestones.
- Identification and devising strategies for ensuring risk mitigation. As said by Peter Shergold, "a policy which is embraced by a minister, approved by cabinet, and announced publicly, but inadequately delivered, is worse than no policy at all." One general way countries have used to manage risks is to have ex-ante policy assessments as mandatory before a policy is implemented.

3.2.4 Policy Evaluation

Policy evaluation is targeted at measuring the actual effects of legislation on a particular problem, or determining the extent to which a certain policy has achieved its intended results. Included in the policy evaluation process are also lessons for improving the implementation process, leading to the recently emerging concept of MEL (monitoring, evaluation and learning), rather than just traditional M&E (monitoring and evaluation). Policy evaluation can take place at different times – including *ex-ante* assessment, where a blueprint policy document is evaluated for its likelihood of success. Administrators seeking to improve operations may also assess policies as they are being implemented. After policies have been implemented, they can be further evaluated to understand their overall effectiveness.

According to the Community Toolbox (2018) among the issues to consider when focusing on evaluation, is purpose for evaluation. ***Purpose*** refers to the general intent of the evaluation. A clear purpose serves as the basis for the design, methods, and use of the evaluation. Taking time to articulate an overall purpose will stop your organization from making uninformed decisions about how the evaluation should be conducted and used. According to the 2018 Community Toolbox, there are at least four general purposes for which an evaluation has been used for in practice:

- **To gain insight.** This happens, for example, when deciding whether to use a new approach (e.g., would a cluster approach to innovation work for our region?). Knowledge from such an evaluation will provide information about its practicality. For a developing program, information from evaluations of similar programs can provide the insight needed to clarify how its activities should be designed.
- **To improve how things, get done.** This is appropriate in the implementation stage when an established program tries to describe what it has done and the outputs and outcomes. This information can be used to describe program processes, to improve how the program operates, and to fine-tune the overall strategy. Evaluations done for this purpose include efforts to improve the quality, effectiveness, or efficiency of program activities.
- **To determine what the effects of the program are.** Evaluations done for this purpose examine the relationship between program activities and observed consequences. For example, are more companies linked to universities as a result of the program? Programs most appropriate for this type of evaluation are mature programs that are able to state clearly what happened and who it happened to. Such evaluations should provide evidence about what the program's contribution was to reach longer-term goals such as more innovative companies. This type of evaluation helps establish the accountability, and thus, the credibility, of a program to funders and to the country.
- **To affect those who participate in it.** The logic and reflection required of evaluation participants can itself be a catalyst for self-directed change. And so, one of the purposes of evaluating a program is for the process and results to have a positive influence. Such influences may:
  - o *Empower program participants* (for example, being part of an evaluation can increase company's control over the program);
  - o *Supplement the program* (for example, using a follow-up questionnaire can reinforce the main messages of the program);
  - o *Promote staff development* (for example, by teaching staff how to collect, analyze, and interpret evidence); or
  - o *Contribute to organizational growth* (for example, the evaluation may clarify how the program relates to the organization's mission).

Further readings suggested

Borass, S. and Edquist, C. (2013) 'The Choice of Innovation Policy Instruments.' *Technological Forecasting and Social Change*, 80(8): 1513-1522. https://doi.org/10.1016/j.techfore.2013.03.002

Fagerberg. (2015) "Innovation policy, national innovation systems and economic performance: In search of a useful theoretical framework". University of Oslo

Cirera, Xavier, and William F. Maloney (2017) "The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up." Overview booklet. World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IG

3.3 Unit Exercise

(These sets of questions can be used for either a group or individual-based exercise, although generally it is preferable to use it in a group setting to stimulate ideas and informed discussions. When done in groups, each team of 4 to 6 persons answers the following questions, then after 20-30 minutes of putting together their answers each group can present their answers to the big workshop group, in 10-15 minutes each. If the number of workshop attendants is small, then perhaps each individual can answer the questions individually.)

1. Pick any STI policy of your choice in a given country. Discuss it in light of what you just learnt. For example, how and who set the policy agenda; where did the policy issues and objectives come from? What informed this?
2. What instruments were used to implement a policy of your choice? Were policy mixes used? Which one are these?
3. Is the policy monitored and evaluated? If yes, what was the outcome? If not, why do you think?

UNIT 4 THE ROLE OF RESEARCH IN THE POLICY PROCESS

Unit Objectives

This unit is designed to show how in order for STI policies to be evidence-informed, they need to integrate related research. Through this unit participants may be able to consolidate their understanding of the role of knowledge (scientific research) in the process of STI policy, as well as the linkages between scientific research and productive activities in different socio-economic settings. Key to the whole process is the role played by knowledge translation and knowledge brokering.

Unit Outcomes

At the end of this unit, participants should be able to define and distinguish between various conceptual issues on STI related research, policy and policy research. They should be able to articulate, with relevance and examples, the need for strong connections between the two realms of STI and policy through research—particularly research that is relevant, clear and evidence-informed.

Unit Topics to be covered

Research for policy and research about policy (policy research); Policy of research (research policy); Research that influences policy and policy that influences research; The nature of evidence for policy; Knowledge translation and brokering—building a two-way road between STI and policy; and Relevance of STI policy for Africa.

Additionally, under this unit, participants are going to be introduced to the following important terminologies: knowledge translation, knowledge brokering, and the relationship between the two; systems thinking; evidence-informed policy.

4.1 Research and Information

Before we go through topics of this unit, one by one, we find it fruitful to introduce the topics through examples that demonstrate how doing research reveals information and provides new perspectives for solutions that may not have seemed intuitive or reasonable before research took place. Examples are provided in Box 3 and Box 4.

Box 3: Counterintuitive Evidence for Policy

The NYC-RAND Institute (Think Tank) – or NYCRI – in the late 1960s was assigned the task of tackling a problem faced by the Fire Department of New York (FDNY) and improving municipal New York City work on response to fire alarms. 'In the five years from 1963 to 1968, fire alarms in NYC increased 96% from 116,000 to 227,000, while firefighting resources stayed almost the same. FDNY operating expenses were increasing at over 20% per year, largely due to wage increases for its 14,000 uniformed firefighters. Workloads on individual firemen were excessive, with some fire companies responding to alarms more than 8,000 times a year or nearly once an hour, 24 hours a day, 365 days a year. During peak times, some fire companies ran from one incident to another all night long.' (Green and Kolesar, 2004, p. 1003)

'RAND used systems analysis and management science' to address the problems of response time of fire companies to fires. Extensive research was done (on records and field data) and using a generated algorithm they looked at locations of fire companies and relocation as effective to increasing response time (parametric allocation model). This led to closing 6 fire companies and relocating 7 fire companies, without necessarily increasing the FDNY budget and other resources. The relocation was fought in court by neighborhood communities and firefighters, but eventually won because the algorithm was clear. The project won an award in management science, and it 'demonstrated annual savings of $5 million on a base of $375 million operating budget. The Fire project was costing the city about $500,000 a year – less than a single fire company.' (p. 1005)

Source: Linda V. Green and Peter J. Kolesar. 2004. 'Improving Emergency Responsiveness with Management Science ', *Management Science*, 50(8): 1001-1014.

Box 4: Finding the Real Evidence

'Near Amsterdam, there is a suburb of single-family houses all built at the same time, all alike. Well, nearly alike. For unknown reasons it happened that some of the houses were built with the electric meter down in the basement. In other houses, the electric meter was installed in the front hall. These were the sort of electric meters that have a glass bubble with a small horizontal metal wheel inside. As the household uses more electricity, the wheel turns faster and a dial adds up the accumulated kilowatt-hours.

During the oil embargo and energy crisis of the early 1970s, the Dutch began to pay close attention to their energy use. It was discovered that some of the houses in this subdivision used one-third less electricity than the other houses. No one could explain this. All houses were charged the same price for electricity, all contained similar families.

The difference, it turned out, was in the position of the electric meter. The families with high electricity use were the ones with the meter in the basement, where people rarely saw it. The ones with low use had the meter in the front hall where people passed, the little wheel turning around, adding up the monthly electricity bill many times a day.' (Meadows, 2009, p. 10)

Source: Donella H. Meadows. 2009. *Thinking in systems: a primer*. London: Earthscan.

4.2 Types of Relations Between Research and Policy

Since policy is the orientation of governance – i.e. the details and technicalities of what is pursued and how it is pursued – it should be self-evident that, in the modern world, many orientations of governance need to be based on, or informed by, realities. Yet, in our modern, reality is not always a face-value experience. Rather, we understand broad and/or complex realities (such as patterns, tendencies and results of experimentation) through scientific research. It follows that, if we need to consult scientific research to understand reality (or realities, or many aspects of reality) then we need scientific research to make sound policies.

There are, broadly, at least three types of relations between research and policy, in any given state. The three types apply to STI related policy.

The most common type – and the one often referred to when speaking about STI policy research – is research for policy and research about policy (i.e. **policy research**). This type of research is characterized generally as research that is undertaken with the purpose of informing policy or studying the consequences of policy. Examples of informing policy include clarifying the possible choices of policy, such as identification of problems/issues and causes of the problem (for a particular issue or sector), or filling the knowledge gaps in the strategies declared to achieve a pre-determined objective (such as increasing the number of engineers in the labour market, or increasing local content in the pharmaceutical sector), or mapping a system of actors and information that should inform particular policies (i.e. mapping the value chain of a particular cash crop in a country or region, or mapping the innovation system actors for local small manufacturing industries). As for examples of studying the consequences of policy, they include evaluating how some laws of lake fisheries affected the biome of the lake, for a long period, and how it affected the local economy that is dependent on fisheries, or a similar evaluation study on the use of pesticides for a particular crop or natural resource, or identifying the incentives and regulation packages that tend to fuel innovation in particular contexts (e.g. country, sector, firms).

Such research can also work on larger, systemic scales. For example, when a state, or province or municipality, intends to build an industrial park, or industrial parks, a number of variables need to be clarified through scientific research to determine the best location of parks according to where types of industries are more relevant and which types of industries go well together (industrial metabolism). Additionally, when planning to meet energy needs, it is needed to assess the capacity of the country and potential sources of energy along with potential capacity of production, etc. These required information for decision-making are essentially information that can only be provided by science and technology-based research.

Policy research, therefore, informs policy in multiple ways, and enhances the policy environment as well as increases the chances of better policies (Eboh, 2014). The relationship may even be more direct in terms of saying that policy research provides evidence for policies, and policies that are made without evidence are running the high risk of being crude guesswork with a lot of wasted costs (of various forms) that come with that.

Policy research, as described above, has also been called 'the Science of Science Policy' (SoSP) (Fealing et al., 2011), as it generally refers to the scientific enterprise that seeks to help improve decision making based on scientific endeavors (both basic and applied research). In other words, SoSP is about building a scientific field of making the best use of scientific knowledge and findings in policy.

Additionally, one particular field which seems to have grown to be very useful for policy research is 'systems thinking' (and complexity studies): a way of viewing various phenomena as 'systems', i.e. sets "of things—people, cells, molecules, [machines, procedures, etc.]—interconnected in such a way that they produce their own pattern of behavior over time" (Meadows, 2009, p. 2). Systems thinking, and complexity studies, is becoming a significant genre of policy research, due to its ability to connect elements and causalities, related to any public phenomena, in a way that helps in identifying good policy choices and strategies through identifying 'leverage points', or points of intervention in the system that will allow a wider effect on the entire system by manipulating only limited variables that relate to those points. Systems thinking uses systems mapping to understand the elements, relationships and information that together form a system, with distinct patterns of behaviour, and how to decode and list leverage points (Williams and Baxter, 2014).

> "A System is a set of elements or parts that is coherently organized and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its 'function' or 'purpose.'"
>
> *Donella Meadows*
>
> "The ability to think and act systemically is the greatest intellectual and practical challenge of this century."
>
> *Geoff Mulgan*

The second of the types of relations between research and policy is 'policy of research' (i.e. **research policy**), which refers to the realm of policies that are designed and implemented to manage and/or guide activities of research, within a country, region, or organization. It is an area of policy that is mainly about managing and fostering research, as well as disseminating research findings.

When it comes to research policy, however, we find that it is often housed within bodies, or agencies, or departments. These bodies are responsible for making or advising the policy responsible for shaping the research environment. For example, science granting councils (SGCs) play the role of either policy formulating, or advising, with regards to how research takes place within their countries. They play part in setting research priorities, management practices and funding streams, all of which shape the research environment in that country; not to mention their often-direct involvement in drafting policy blueprints for STI and relevant research. Similarly, R&D Parastatals (Public Technology Intermediaries) and state centres of excellence play a significant role in defining the enabling environment for research, in particular areas, in any country. In many countries, both developing and developed, public technology intermediaries are responsible for defining frontier areas of applied research, or R&D, in their countries (Lall and Pietrobelli2005; Sheikheldin 2018).

It also needs to be added that research policy itself should be informed by policy research, meaning that, it is not possible to have good research policy without good policy research. In other words, the mandate of research policy should rest on the shoulders of policy research.

The third of the types are **research that influences policy and policy that influences research**. Such endeavors – either research or policymaking – are ones that were not initially undertaken with the other side particularly in mind, but eventually impacts the other side.

A good example for this type is how climate and environmental research continued to accumulate evidence for climate change, through multiple research agenda that were not necessarily working together to influence policy. When the evidence collected from all these scientific studies over time led to clarifying that climate change is impacting the planet on serious levels, and that humans are mainly responsible for climate change, policy became involved. At the global level, the Intergovernmental Panel on Climate Change (IPCC) was formed to confirm the science behind climate change and propose policies to deal with climate change mitigation and adaptation. At the national and regional levels, ministries and state agencies became responsible for policies and information about climate change impacts and how to have healthy economies without furthering global warming. That, in turn, made research about climate change mitigation and adaptation a large research area.

In understanding STI policy and research, it is important to understand how types of relations take place in reality, in order to observe and analyze their influences on society, and how they contribute to leading to good or bad policies, directly or indirectly.

4.3 The Nature of Evidence for Policy

Whether it comes from natural science or social sciences, policy eventually becomes social. This is an important note to be considered. Policies are political, and socio-political, decisions, based on social-political goals and using social-political means to materialize. Therefore, policy relating to science, technology and innovation are not, accordingly, 'scientific or technological' policies. They may use evidence generated through the natural sciences (basic and applied) and they may concern aspects of regulating or using the natural sciences, but what we call policy (whether public or agency-focused) is a social/organizational decision made and enacted by social procedures. Therefore, policies can be evidence-based, and evidence-informed, by science, technology innovation, and remain not an exact science but an area of judgement; only that there is a difference between informed judgement and mere judgement.

This takes us to the discussion of the difference between 'evidence-informed policy' vs. 'evidence-based policy'. Both terms are currently in use, sometimes interchangeably, but at times they are used to reflect small differences.

There is a difference of degree between 'evidence-based' and 'evidence-informed'. Some policies can be more straight-forward 'evidence-based' to their nature that is not much contested in the public domain. For example: aviation safety policies, and construction and industrial safety policies, should be generally evidence-based. They should be based on clear data about limits to human safety, capacity of machinery, historical records, etc. There are not likely to be heated public debates about factors of safety once presented with scientific, analyzed data. On the other hand, some policies are more contentious on the public domain, and are not likely to be simply 'evidence-based'. In that case, they should be, at least, evidence-informed.

> "We use the term "evidence-informed" instead of "evidence-based" because evidence is only one part of public policy. Other factors, including the expression of public preferences (through voting and ongoing civic participation), political dynamics, public-sector implementation capacity, and budget constraints do — and should — play a role. For the purposes of this strategy, "evidence" includes traditional and new sources of data, policy research, and impact evaluation, with a particular emphasis on those that are relevant, timely, and practical for government decision making throughout the policy cycle, including implementation. Data, research, and evaluation findings can play a role in helping policymakers decide which issues to focus on, understand the scope of problems, and inform policy responses." (Hewlett Foundation 2018, p. 2).

For example, industrial strategies, agricultural production, and investments in particular areas of technological enhancement, all of these are areas of policy that require evidence, as described above, but are not necessarily only influenced by that evidence. They are not 'evidence-based' but to be sensible they need to be 'evidence-informed'.
This also helps to understand the relationship between 'policy' and 'politics'. In many languages (such as French, Arabic, German, etc.) the words for 'policy' and 'politics' are the same word. English is perhaps one of the few languages that differentiate between the two (and Swahili as well). That is because in reality the two are not just related, but also highly overlapping. To summarize the relationship between policy and politics, we can say that policy is but a softer, more technical form of politics.

4.4 Knowledge Translation and Knowledge Brokering

While they may have the same goals in mind, 'science people' and 'policy people' operate under different short-term and long-term imperatives. This makes their usual communication channels filled with misunderstanding, miscommunication, and sometimes conflicts. "The cultures of the science and policy communities are quite different in terms of timescale, language, academic background and incentive structure, to name a few" (Sheikheldin, Krantzberg and Schaefer, 2010, p. 912). The task of communicating specific policy concerns to science people and making sure the corresponding science is communicated back in the right format, is a key and critical task. The process to achieve this task is called knowledge translation (in this case science-policy translation) and the activities that focus on making this translation connect both sides is called knowledge brokering.

This takes us to the role of bodies, institutions and teams that primarily work on achieving this connection, that is, knowledge brokering through various activities and approaches. This is particularly important within the STI policy area; and to a large extent this role is normally performed by think tanks dealing policy research in STI.

Think tanks (or policy institutes) are organizations that conduct research and advocacy activities (and sometimes capacity building activities: training, sponsorship, consultancy and mentorship) for the purpose of influencing policies (national or organizational) on various topics – e.g. economy and trade, technology and industry, health, education, food systems, justice, public works, culture, military, resource management, ecosystem issues, finance, logistics – through knowledge, evidence and strategy. Think tanks mainly generate and synthesize knowledge and use it to advice and advocate for improving, supporting, modifying or changing particular policies in order to influence desired change. Advocacy can also be understood as 'linking research to policy'.

Think tanks can be independent, state-sponsored, or mainly funded by distinct or private organizations (such as corporations) to do the work that is explained above for particular areas or agenda. Think tanks serve as expert, credible advisors in their specializations. Knowledge brokering, or knowledge bridging, is essential to their work. It can be argued that successful think tanks can only be called so if they are successful in knowledge translation, brokering and bridging.

4.5 Relevance of STI Policy for Africa

Important questions should be asked, regarding STI policy in Africa:

- Does Africa need stronger connection between STI research and policy?
- What are the sectors that require such connection the most?
- What is the role of organizations such as Science Granting Councils?
- Can better STI policies help African countries achieve their SDGs?
- How are the African frameworks of STI Strategy for Africa (STISA), 2024 and Agenda 2063, influencing STI policy research? (or perhaps, should be influencing)

These questions help contextualize the issues addressed above, and contextualization is important for research. STI policy research agenda are often set with context in mind. Currently, there may be three frameworks that Africa overall is working within, in relevance to STI; and those two frameworks are: Science, Technology and Innovation Strategy for Africa (STISA), 2024, Agenda 2063 and the SDGs (Sustainable Development Goals). Such broad frameworks (and yet clear in their support for STI enhancement) drive agenda that policy must respond to, and in order to respond well, evidence is required.

These frameworks are also instances where policy influences research, as discussed earlier. Consequently, it can trigger a host of activities of policy research (and research policy) for driving, enhancing and improving science, technology and innovation in Africa.

Further readings suggested

Eboh, E. C. (2014). *Using Research to Influence Public Policy: What Works and How*. Abuja: Institute for Public Policy Analysis and Management.

Fealing, K. H., Lane, J. I., Marburger III, J. H., and Shipp, S. S. (Eds.). (2011). *The science of science policy: A handbook*. Stanford University Press

Sheikheldin, G., Krantzberg, G., and Schaefer, K. (2010). 'Science-seeking behaviour of conservation authorities in Ontario.' *Environmental management*, 45(5), 912-921.
Meadows, D. H. (2009). *Thinking in systems: A primer*. London: Earthscan.

4.6 Unit Exercise

(These sets of questions can be used for either a group or individual-based exercise, although generally it is preferable to use it in a group setting to stimulate ideas and informed discussions. When done in groups, each team, of 4 to 6 persons, takes one of the case studies (provided below) and answers the following questions according to their case study. After 20-30 minutes of putting together their answers, each group can then present the case and their answers to the big workshop group, in 10-15 minutes for each group. If the number of workshop attendants is small, then perhaps each individual could be given a case study to do the same, above.)

Questions (for each case study):

1. In what way was research relevant to policy in this case study? (please present a summary of the case study to the larger group)
2. What was the policy relevant to the issue(s)? (geographically and sector-wise)
3. Was research used to make/change policy?
4. If yes, in what way?
5. If no, how would it have possibly influenced policy?
6. If you were given a case study of evidence-informed policy, how would you describe the importance of STI research to making and implementing effective and efficient policies in this case?
7. If you were given a case study where there was no policy that benefited from the research, can you determine what sort of research that took place (research for policy, research about policy, or neither of the two)?
8. Are there any relevant topics from your region/countries that you think policy would benefit, or is benefiting, from STI research? (one or two topics to mention briefly).

Case Study 1 (for Unit 4 Exercise)

Spruce Budworms, Firs, and Pesticides

'Tree ring records show that the spruce budworm has been killing spruce and fir trees periodically in North America for at least 400 years. Until this century, no one much cared. The valuable tree for the lumber industry was the white pine. Spruce and fir were considered "weed species." Eventually, however, the stands of virgin pine were gone, and the lumber industry turned to spruce and fir. Suddenly the budworm was seen as a serious pest.

So, beginning in the 1950s, northern forests were sprayed with DDT to control the spruce budworm. In spite of the spraying, every year there was a budworm resurgence. Annual sprays were continued through the 1950s, 1960s, and 1970s, until DDT was banned. Then the sprays were changed to fenitrothion, acephate, Sevin, and methoxychlor. Insecticides were no longer thought to be the ultimate answer to the budworm problem, but they were still seen as essential. "Insecticides buy time," said one forester, "That's all the forest manager wants; to preserve the trees until the mill is ready for them." By 1980, spraying costs were getting unmanageable—the Canadian province of New Brunswick spent $12.5 million on budworm "control" that year.… And, in spite of the sprays, the budworm was still killing as many as 20 million hectares (50 million acres) of trees per year.

C. S. Holling of the University of British Columbia and Gordon Baskerville of the University of New Brunswick put together a computer model to get a whole-system look at the budworm problem. They discovered that before the spraying began, the budworm had been barely detectable in most years. It was controlled by a number of predators, including birds, a spider, a parasitic wasp, and several diseases. Every few decades, however, there was a budworm outbreak, lasting from six to ten years. Then the budworm population would subside, eventually to explode again.

The budworm preferentially attacks balsam fir, secondarily spruce. Balsam fir is the most competitive tree in the northern forest. Left to its own devices, it would crowd out spruce and birch, and the forest would become a monoculture of nothing but fir. Each budworm outbreak cuts back the fir population, opening the forest for spruce and birch. Eventually fir moves back in. As the fir population builds up, the probability of an outbreak increases— nonlinearly. The reproductive potential of the budworm increases more than proportionately to the availability of its favorite food supply. The final trigger is two or three warm, dry springs, perfect for the survival of budworm larvae.… The budworm population grows too great for its natural enemies to hold in check—nonlinearly. Over a wide range of conditions, greater budworm populations result in more rapid multiplication of budworm predators. But beyond some point, the predators can multiply no faster.…

Now only one thing can stop the outbreak: the insect reducing its own food supply by killing off fir trees. When that finally happens, the budworm population crashes—nonlinearly. The reinforcing loop of budworm reproduction yields dominance to the balancing loop of budworm starvation. Spruce and birch move into the spaces where the firs used to be, and the cycle begins again. The budworm/spruce/fir system oscillates over decades, but it is ecologically stable within bounds. It can go on forever. The main effect of the budworm is to allow tree species other than fir to persist. But in this case what is ecologically stable is economically unstable. In eastern Canada, the economy is almost completely dependent on the logging industry.

…The forest management practices have set up what Holling calls "persistent semi-outbreak conditions" over larger and larger areas. The managers have found themselves locked into a policy in which there is an incipient volcano bubbling, such that, if the policy fails, there will be an outbreak of an intensity that has never been seen before."

Source: Donella H. Meadows. 2009. *Thinking in systems: a primer*. London: Earthscan., pp.92-94

Case Study 2 (for Unit 4 Exercise)

DDT: A Fallen Angel?

'DDT, the most powerful pesticide the world had ever known, exposed nature's vulnerability. Unlike most pesticides, whose effectiveness is limited to destroying one or two types of insects, DDT was capable of killing hundreds of different kinds at once. Developed in 1939, it first distinguished itself during World War II, clearing South Pacific islands of malaria-causing insects for U.S. troops, while in Europe being used as an effective de-lousing powder. Its inventor was awarded the Nobel Prize.

When DDT became available for civilian use in 1945, Nature writer Edwin Way Teale, warned, "A spray as indiscriminate as DDT can upset the economy of nature as much as a revolution upsets social economy. Ninety percent of all insects are good, and if they are killed, things go out of kilter right away." **Rachel Carson's book '*Silent Spring*' came out in the 1960s, and alarmed readers across America and brought a howl of indignation from the chemical industry. The book showed concern regarding the effects of chemical pesticides on humans and on the environment. DDT severely reduced the rate of reproduction in many fish and birds.**

A huge counterattack was organized and led by Monsanto, Velsicol, American Cyanamid duly supported by the Agriculture Department. One of the book's most controversial claims was that DDT is a carcinogen. Carson didn't seem to take into account the vital role (DDT) played in controlling the transmission of malaria by killing the mosquitoes that carry the parasite. It can be argued that the anti-DDT campaign she inspired was responsible for almost as many deaths as some of the worst dictators of the last century.

President John F. Kennedy ordered the President's Science Advisory Committee to examine the issues that Carson's book raised. Its report thoroughly vindicated both *Silent Spring* and its author. As a result, DDT came under much closer government supervision and was eventually banned. The public debate moved quickly from *whether* pesticides were dangerous to *which* pesticides were dangerous, and the burden of proof shifted from the opponents of unrestrained pesticide use to the chemicals' manufacturers. An end to the continued domestic usage of the pesticide was decreed on June 14, 1972 when the Environmental Protection Agency, USA, issued an order finally cancelling nearly all remaining Federal registrations of DDT products. Public health, quarantine, and a few minor crop uses were excepted, as well as export of the material.

Rachel Carson had made a radical proposal: that, at times, technological progress is so fundamentally at odds with natural processes that it must be curtailed.... the threats Carson had outlined -- the contamination of the food chain, cancer, genetic damage, the deaths of entire species -- were too frightening to ignore. For the first time, the need to regulate industry in order to protect the environment became widely accepted, and ***environmentalism was born***.

Banned under the Stockholm Convention on Persistent Organic Pollutants under the United Nations Environment Programme (UNEP) auspices in May 2001. The position of the WHO for DDT is the mirror image of UNEP. India has sought exemption for the use of DDT as an effective prevention against malaria. Response: the National Anti-Malaria Programme should abide with the UNEP/WHO call, reducing reliance on DDT and investing resources in research and development.

In 2006, the World Health Organization suggested the resumption of the limited use of DDT to fight malaria. They called for the use of DDT to coat the inside walls of houses in areas where mosquitoes are prevalent. Dr. Arata Kochi, WHO's malaria chief, said,"One of the best tools we have against malaria is indoor residual house spraying. Of the dozen insecticides WHO has approved as safe for house spraying, the most effective is DDT".

Source: Gail Krantzberg, 2008, Course material for 'Emerging Issues and Public Policy', Centre for Engineering and Public Policy, McMaster University.

Case Study 3 (for Unit 4 Exercise)

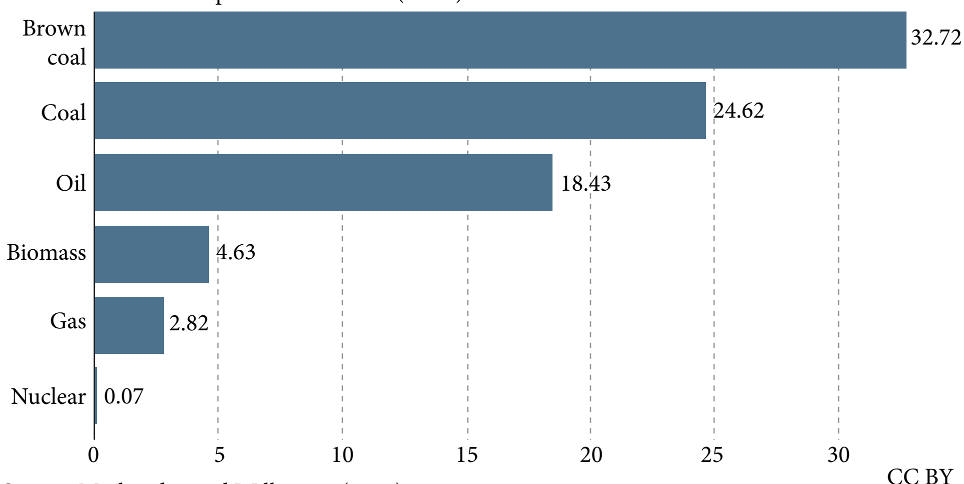
Nuclear Energy as alternative to fossil fuels?

'France is hailed by many as an energy model of the future due to the fact that75% of its electricity is generated from nuclear energy stations, which makes France the leading low-carbon economy among the industrialized countries and arguably in the world. In addition, the Canadian province of Ontario generates 50% of its electricity through nuclear power stations.

The Ontario Power Generation Corporation states that nuclear energy "has two major benefits - low operating costs and virtually none of the emissions that lead to smog, acid rain or global warming."[9] Other nations may have to take bolder policy decisions and shift to nuclear energy, **especially seeing as the popular perceptions about the dangers of nuclear energy do not match the empirical data and the majority voice of technical experts (OECD 2010). (See Figure)**

Death rates from enery production per TWh

Death rates from air pollution and accidents related to energy production, measured in deaths per terawatt hours (TWh)



Source: Markandya and Wilkinson (2007)

Note: Figures include deaths resulting from accidents in energy production and deaths related to air pollution impacts. Deaths related to air pollution are dominant, typically accounting for greater than 99% of the total.

And while solar, wind, tide and geothermal energy sources are not yet strong, affordable, or efficient enough to replace fossil fuels, there is certainly more room for improving the quality and quantity of these renewable resources. Germany, for instance, has been able to produce 18 billion kilowatt-hours from solar photovoltaic energy in 2011, and is planning for a target of 35% of its power generation from renewable energy sources by 2020. Some sources are even hopeful that 100% of Germany's power – with the right technology and policy combination – can be generated from renewable energy sources by the year 2050.

[6] Ontario Power Generation Inc. – OPG (2000-2013). "Nuclear Power". Retrieved October 15, 2013 from: http://www.opg.com/power/nuclear/

Other parts of the world which are endowed with more solar and/or wind energy exposure than Germany – such as most parts of Africa – can invest more on that track. **The main recipe that is required for these types of responses to climate change to work, has both technology and policy as critical ingredients.'**

Source: Gussai Sheikheldin. 2018. *Liberation and Technology: Development possibilities in pursuing technological autonomy*. Dar es Salam: Mkuki na Nyota Publishers. pp. 76-77.

Case Study 4 (for Unit 4 Exercise)

Integrating health care and industrialisation in East Africa

'It's no secret that health care and industrial production are intertwined: the enormous demand for high-quality health care commodities requires robust and efficient supply chains to meet it. Yet many low-income countries lack industrial policy that addresses the health sector. In both Tanzania and Kenya, for instance, the public health sectors suffer from severe supply shortages, which contributes to inadequate and exclusionary health care. Meanwhile, rising expenditure by donors on medicines for these countries has led to an over-reliance on imports, raising local concerns about how those imports are directed and how they may be stifling local industry.

Researchers from Tanzania [REPOA], Kenya [ACTS], and the United Kingdom [Open University] who had been studying the situation saw enormous potential to better align the health and industrial policies within each country. Greater integration between industrial and health care sectors, they believed, could benefit both, improving the quality and accessibility of health care and fostering greater industrial innovation and employment. Thus, with funding from the DEGRP [DFID-ESRC Growth Research Programme], **the researchers sought to examine and help to exploit the synergies between the two sectors by studying the supply chains of health care products and supplies in Tanzania and Kenya….**

The team began their project by interviewing professionals working at health facilities and pharmacies in four districts (two rural and two urban) in each country. In order to map out the supply chains, the researchers collected data on the availability of different medicines and supplies, and asked individuals about their experiences procuring or purchasing drugs and supplies. In June 2013, the researchers presented their initial findings in the form of working papers at the project's first workshop in Dar es Salaam…. Attendees included members of Tanzania's Ministries of Health and Industry as well as other key stakeholders, including private industrialists, from the industrial and health sectors in Tanzania and Kenya. Through roundtable discussions, the attendees and researchers analysed the findings and shared their feedback, developing a better understanding of the challenges facing the health sectors and debating some possible solutions. Next, the project team moved on to the industrial sector, where they interviewed manufacturers of medicines and other health care supplies in Kenya and Tanzania…. In their effort to identify opportunities to enhance local manufacturing and improve access to medicines and health care supplies, the researchers discovered that conditions for domestic manufacturers were becoming more competitive; most manufacturers pointed to a growing need for technological advancement and innovation. **From these conversations, the project team began to craft a set of policy proposals for each country that could both improve health care and stimulate local industry….**

An instrumental impact of the project was **its contribution to a key national policy document in Tanzania: the new National Five-Year Development Plan [2016-2020]. The document, which identifies the pharmaceuticals sector as a priority sector for development, draws directly from two policy briefs written by the project team, stating: 'The Plan targets pharmaceutical industries because industrial production of health supplies can improve health care, which is necessary for a healthy, productive population. The Plan notes that, local production can enhance access to medicines' (p. 49)…** The team pointed to the importance of including policymakers from the Kenyan and Tanzanian governments in the research project from the start, not as passive recipients of the findings and policy recommendations, but as active participants in the process of interpreting and debating them.'

Source: Madeline McSherry. 2017 (July). Integrating health care and industrialisation in East Africa: Impact case study. a DFID-ESRC Growth Research Programme (DEGRP) report. pp. 4-11.

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