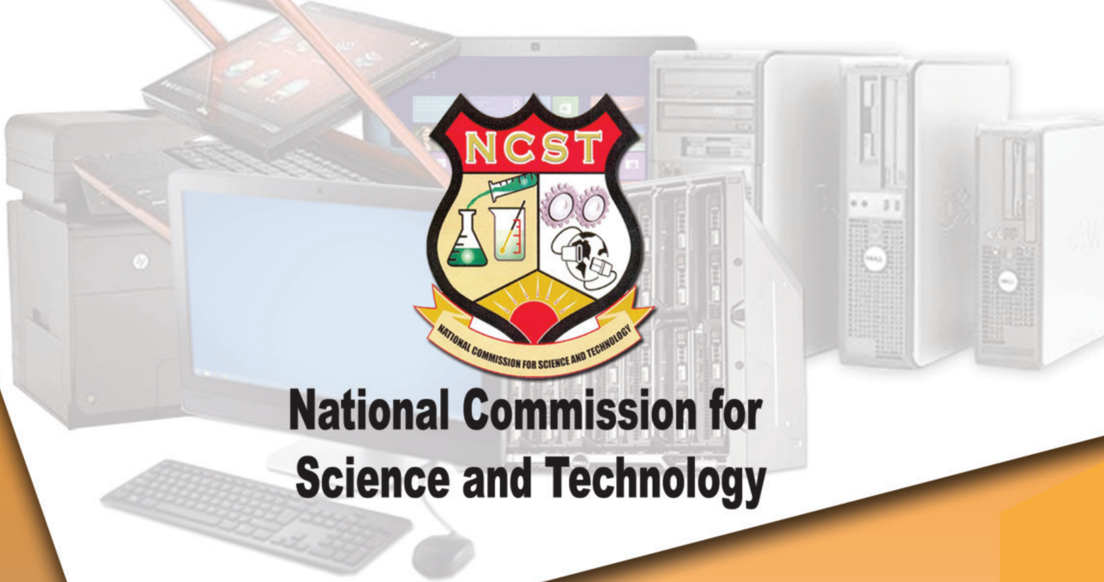

National Commission for Science and Technology

Companion Document to the State of Science and Technology in Malawi 2010 - 2011 Report

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List of Abbreviations and Acronyms

SSTR	State of Science and Technology Report
STI	Science, Technology and Innovation
NEPAD	New Partnership for African Development
R & D	Research and Development
MOSTE	Ministry of Science, Technology and Environment
STE	Science and Technology Services
ICT	Information and Communication Technologies
GDP	Gross Domestic Product
OPC	Office of the President and Cabinet
GERD	Gross Expenditure on Research and Development
ASTIII	African Science, Technology and Innovation Indicator Institute
NSO	National Statistical Office
WTO	World Trade Organisation
ARIPO	African Regional Intellectual Property Office
USPTO	United States Patent and Trademarks Office
IPR	Intellectual Property Rights
HIV	Human Immunodeficiency Virus

Preface

The State of Science and Technology Report (SSTR) provides a comprehensive overview of Malawi's STI infrastructure beginning with a description (in Chapter 1) of the policy, regulatory, institutional and organizational framework for STI. The SSTR highlights strides in science, technology and innovation in the following areas: education and training; intellectual property; information, communication and technology; biotechnology; irrigation, water and sanitation; health; agriculture; energy and mining; genetic resources; climate change and meteorological services; and transport and construction.

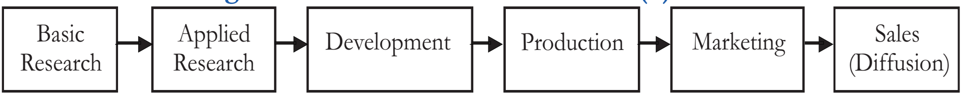
The State of Science and Technology Report has not focussed on areas of research and development financing, expenditure and human resource. A separate report capturing these indicators has been prepared by the Department of Science and Technology in the Ministry of Education, Science and Technology under the NEPAD African Science, Technology and Innovation Indicators Initiative.

The action taken by the National Commission for Science and Technology to produce the first ever State of Science and Technology Report is in compliance with provisions of the National Science and Technology Policy (2002) and the Science and Technology Act (2003). The document, prepared as a companion to the State of Science and Technology Report 2010-11 is aimed at providing its readers with frameworks that enable better understanding and interpretation of the issues it has raised, and highlights factors and conditions that either propel or retard the development and application of science and technology and the emergence of innovation in the country.

1.0 Knowledge: The Basis of Development

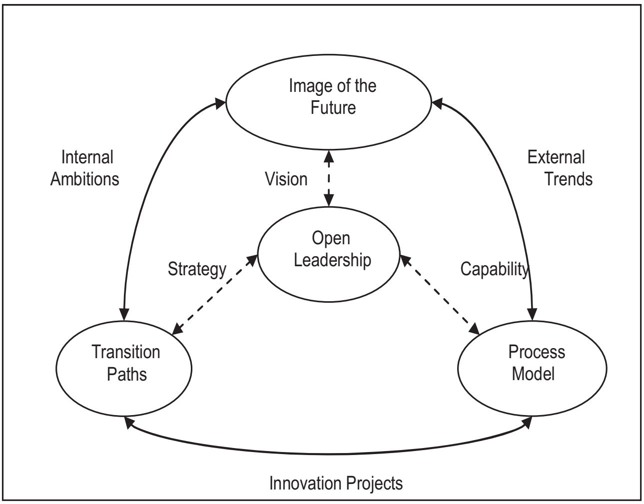
In 1945, after the Second World War, a landmark Report was produced for the American Government that aptly conceived science as an 'endless frontier' since, and rightly so, existing knowledge forms a basis for new knowledge *ad infinitum*. The Report greatly influenced the perception that innovation, the process of applying knowledge to create new ways of doing things, starts with investment in basic science followed by use of the basic knowledge so generated to undertake applied research before developing related prototype products. It was thought further that this in turn enables creation of production capacity for the goods and services that are then marketed and sold to end users (Figure 1).

Figure 1: From Science to Market (1)



It is now known that the story is much more complex than is perceived through the linear model in Figure 1. It is, nonetheless, (at any level of analysis - micro and macro) , informed greatly by a number of concepts that are summarized in Figure 2 with open leadership as the basis.

Figure 2: Basis for Re-Thinking 'From Science to Market'



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1 This document focuses at the macro level of analysis while building on micro-foundations (firms and individuals).

2 Open leadership entails recognizing the limits to rationality by leaders thereby enhancing their propensity to absorb external knowledge (what they do not know) while optimizing utility of their internal knowledge (what they know already). Open leaders guard against short-term thinking by focusing on the longer-term strategic direction in which they want to steer their organization (vision) and on building coalitions of capable partners.

First are the *images of the future* that a nation creates for itself. In the context of the United States of America, one of the images of their future is captured by following telling thoughts regarding free international trade (market liberalization):

> *"....free trade is the ideal, and the US will proclaim the true cosmopolitan principles when the time is ripe. This will be when the US has a hundred million people and the seas are covered by her ships; when American industry attains the greatest perfection, and New York is the greatest commercial emporium and Philadelphia the greatest manufacturing city in the world: and 'when no earthly power can longer resist the American Stars, then our children's children will proclaim freedom of trade throughout the world, by land and sea'"* (Dorfman, 1947, cited in Reinert, 1995).

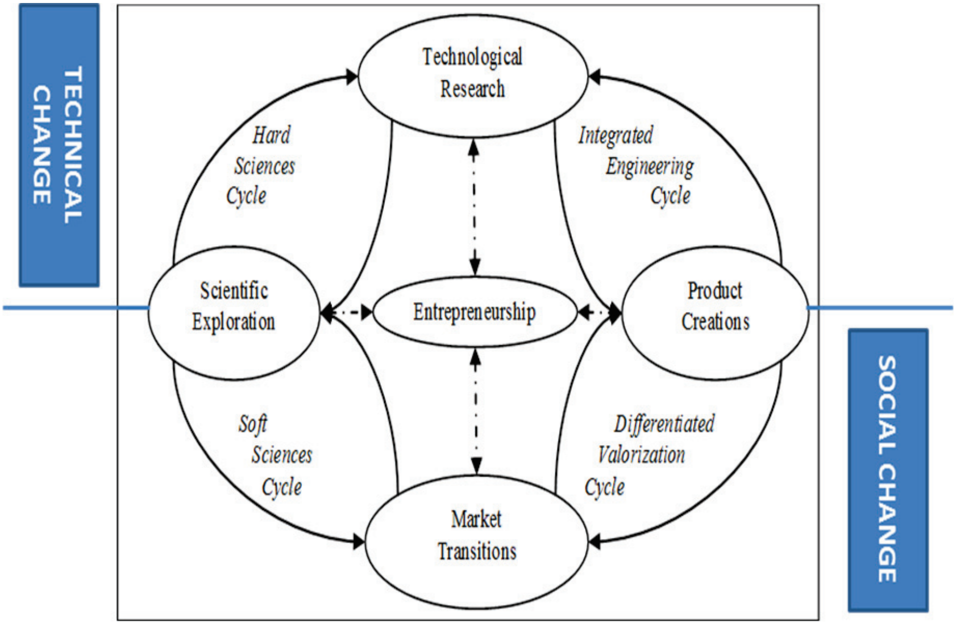
In time, the US realized this vision. It is today a powerful trading nation of much more that 100 million people. Philadelphia (and other cities and regions e.g. Silicon Valley), is a strong manufacturing base while New York is a commercial emporium. In spite of the emerging developments in China, the US is the leading nation with respect to a wide range of high quality goods and services. It is thus not a small matter that Malawi in 1998 created a vision to become a middle income country that is technologically-led by 2020.

The second issue is captured, in Figure 2, by the term 'Transition Paths'. This is the extent to which the choices a country makes, often expressed as National Development Plans/Strategies influence its development trajectory. For example, deliberate choices regarding its education system enabled Korea to move from labour intensive approaches to production of goods and services to those imbued with high knowledge intensity. This Korea transition from an economy dependent on agriculture to what it is today: a competitor of the US in high-tech production capabilities. By contrast, an education system with low enrolment ratios at all levels in Malawi, whether by default or design, has fostered a labour intensive approach to production of goods and services with low productivity and high vulnerability to climate induced shocks.

The third concept is what is shown in Figure 2 as 'Process Model' where focus is on developing national technical and social capabilities. It is with respect to these matters that the linear model in Figure 1 fails the most. This is so because the linear model plays down the role of feedback that often comes from interactions between the technical system which underpins technical change, and the social system which, by contrast, underpins social change (Figure 3).

3 Enrollment ratios relate to the proportion of students who move from one level of education to the next. The education system in Malawi has low enrolment ratios especially between secondary and tertiary levels (Chapter 2 of SSTR)

Figure 3: From Science to Market (1)



As can be recognized in Figure 3, knowledge generated in the technical system by hard sciences such as physics, chemistry and mathematics is converted to new or improved products and services (Product Creations) through application of integrated engineering capabilities that are vital for technological research. By contrast, scientific research in soft sciences such as economics, accounting, psychology, sociology and management science play a useful role in understanding the need for the outputs of both hard scientific and technological research to meet requirements for economic viability and social acceptability i.e. valorization thus underpinning evolution of new markets (market transitions) . The linear model also subsumes the important role of entrepreneurship.

As a result of these broader perspectives, current understanding of how knowledge facilitates development is that it involves cyclic interactions with multiple feedbacks and feed-forwards (also called feedback loops in systems analysis) within and between scientific research in the hard sciences and technological research as drivers of technical change and scientific research[5] in soft sciences as drivers of social change. In a nation state such as Malawi, the cyclic interactions occur in what are called national scientific, technological and innovation systems .

4 The rapid diffusion of cellular telephones and its related services is an example of how products influence social change.

5 Use of the word 'systems' is made to stress the multiplicity of science, technology and innovation fields in which specialized communities and actors operate.

2.0 Malawi's Scientific, Technological and Innovation Systems

Four sub-systems define the characteristics of a nation's scientific, technological and innovation system whose prime functions are discovering, inventing, transferring and promoting the application of knowledge with a view to achieving national goals. The first one is the Planning and Decision-Making Sub-system which is the top level in a national STI system. As implied, planning and decision-making are undertaken on a comprehensive national scale at this level. It is also at this level that inter-ministerial co-ordination should be achieved. In many countries this level takes concrete form in the shape of a Ministry. In Thailand and Malaysia for example, this is achieved through the Ministry of Science, Technology and the Environment (MoSTE). It can also exist as a special council closely related to a very high government office. In Malawi, the science and technology portfolio is, at this level, organized as a Directorate in the Ministry of Education, Science and Technology headed by an Acting Director.

The second sub-system is that which focuses on promoting, financing and coordinating matters related to science, technology and innovation. A number of organizations are established under this sub-system as agents that promote, finance and coordinate research and development (R&D) within various sectors of national economic activities. Research councils for specific economic sectors such as agriculture, medicine and industry whose members are drawn to represent different spheres of science and technology, government and industry are typical. The National Commission for Science and Technology is Malawi's apex organization at this level while the Registrar General's Department performs the important role of safeguarding intellectual property rights.

The third sub-system comprises private and public research performing organizations where scientific and technological research is actually executed. They take the form of networks of research centres/stations, and universities and their special schools or centres. The extent and diversity of this network normally increases as the socio-economic development of a particular country progresses. The Agricultural Research and Extension Trust and Forestry Research Institute are examples of private and public research performing organizations respectively.

The fourth sub-system is where the respective organizations provide complementary scientific and technological services (STS) required for the execution of scientific and technological research and for the production of goods and services. Examples include documentation centres and national meteorological services and bureau of standards.

3.0 National Science, Technology and Innovation: Challenges and Framework Conditions

National science, technology and innovation systems are subject to a range of challenges and framework conditions that militate and enhance their efficiency and effectiveness, respectively.

3.1 Challenges

The major challenge in the fields of science, technology and innovation with respect to economic growth and development is that they deal with knowledge. Scientific research generates basic knowledge; technological research enables knowledge to be embodied in products (including capital goods such as machines and other technological artifacts) and services while innovation entails applying knowledge in new ways to establish new opportunities capable of creating new sources of wealth. At the basic level, it is individuals who possess knowledge although knowledge can be said to reside in groups and organizations. Thus, if Malawi is to become a technologically-led middle income country, it is important to empower and enable individuals to generate and apply knowledge that leads to creation of wealth in organizations, especially firms. It is when firms grow that the economy can grow; not the other way round. Growth begins at the micro level. However, it is supported by policies that enable economic actors to innovate, that is: do things differently and better because they have acquired new capabilities.

The capacity of Malawi's firms and other economic actors to innovate can be militated by a number of systemic failures that disable innovation processes. Like any nation's science, technology and innovation systems, the Malawi systems are subject to challenges emanating from the failures summarized in Table 1.

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6 The challenge arises from differences in the understanding in economics of how knowledge influences economic growth and development. The dominant view, which invariably informs public policy, is that knowledge is not internal to the production system: what economists call 'the production function'. Rather knowledge can be sourced almost freely from the environment. Consequently, at base, there is no need to exert effort to generate it from within. This dominant view governs the global economy at the moment with the implication that for poor developing countries such as Malawi, it is not efficient to purposefully invest in knowledge generation. This is the basis for the so called 'laissez faire' concept to development.

7 This is the other dimension of the challenge of knowledge. It is incomplete to believe that by moving knowledge embodied in products and services knowledge is transferred. Products and services contain static forms of knowledge - a dynamic variable that requires individuals, groups and organizations to constantly learn and innovate as a basis for dynamic as opposed to static efficiency.

8 Firms are understood here in the widest sense and include farming enterprises at household level.

Table 2: Framework Conditions for Innovation

Category	Context/Description
Infrastructural failure	The effectiveness of the science, technology and innovation system is positively correlated with national physical infrastructure (ICTs, roads, energy) and scientific and technological infrastructure (research centres, testing laboratories, availability of skilled workers). Failure of these leads to infrastructural failure.
Transition failures Hard and Soft	A nation's economic performance and its development is influenced by the propensity of its firms to adapt new technological systems that lead to new products and services produced competitively for domestic and global markets. Failure to adapt leads to firms being locked-in low productivity systems.
Institutional failures	Institutions determine behaviour of economic actors by defining rules and norms. Ineffective regulatory and legal frameworks (formal institutions) lead to hard institutional failure. By contrast, failure of social institutions such as political culture and values (informal institutions) leads to soft institutional failure.
Interaction failures	Strong ties between and among individuals as when ethnicity is lauded above nationalism creates blindness to knowledge from outsiders. Weak ties, by contrast, militate against benefits that arise from exploiting complementarities. Both strong and weak ties foster interaction failures limiting knowledge flows.
Capabilities failure	When firms do not learn rapidly they fail to adapt giving rise to capabilities failure.

Source: Woolthuis et al. (2005)

These systemic failures occur because individuals, groups or the organizations in which they operate fail to take action or there are no individuals or organizations that would otherwise take the necessary actions. In the context of science, technology and innovation, the key organizations and groups through which individuals act to mitigate failures are:

- Consumers (including large buyers such as Government): Consumer demand is essential for driving innovation thus science and technology. Large buyers such as Government can perform the function of lead-users who enable firms build confidence in production of new products. Where demand is weak innovation

9 Institutions in this regard does not equate to organizations although some organizations are institutional in nature such as the Police.

is limited and new patterns of consumption do not arise.

- **Firms** ***(Large firms e.g. Press Corporation and Multi-national Corporations e.g. Unilever; Small and Medium Enterprises; Start-up companies, etc.)*****:** Firms are expected to apply knowledge to create value/wealth. Science, technology and innovation will be weak where firms focus on exploiting what they know now without any attention to exploring new and better ways of doing things which can lead, in time, to creation of new streams of income. In this case firms and the macro-economy grow but only incrementally rather than rapidly.

- **Knowledge Institutes** ***(Universities and Research Centres):*** Universities and research centres are essential for effective science, technology and innovation systems since they facilitate economies to generate new knowledge (to country) and absorb knowledge (already existing elsewhere). They constitute important elements of Malawi's knowledge infrastructure.

- **'Third Parties'** ***(Banks and other financial institutions, Consultants, Associations, Venture Capitalists, etc):*** Third party organizations play an important role in facilitating innovation. Banks, for instance, can disable innovation by being overly risk-averse so as to deter start up of new firms and expansion into new economic activities by existing firms. Audit firms are essential for facilitating product and market transitions while business associations foster collective learning by producers. Compared with other countries in the region, fewer firms in Malawi subject their financial performance to scrutiny by external professional auditors.

Government is a primary actor in abating failures across all the categories. For example, tax policies in Malawi are perceived by manufacturing firms to particularly constrain their innovative capability by according similar but imported products a competitive advantage.

3.2 *Framework Conditions*

The importance of science, technology and innovation lies in how they can foster economic development of Malawi. A number of factors defining framework conditions need to be in place for innovation to be facilitated. Table 2 summarizes the essential conditions.

Table 2 : Framework Conditions for Innovation

Condition	Context/Description
Market Conditions	Because consumer demand is central to innovation, the most important quantitative indicators of market conditions are income per capita, overall size of GDP and population density. Other qualitative indicators include: (1) openness of customers to innovation, (2) attitudes of people towards innovation; and (3) acceptance of failure. A population that has a tendency to accept what is offered limits innovation while low acceptance of failure limits entrepreneurship.
Governance	Governance is critical for creation of institutions that foster innovation. Thus, public policy choices, which define the regulatory environment regarding property and business ownership, decision rights and market entry, provide incentives for innovation and entrepreneurship. Politicization of businesses limits institutional conditions related to virtues (e.g. personal and national integrity), risk-taking, responsibility, independence of actors and perceptions on "locus of control" thereby impeding emergence of innovation and entrepreneurship. This makes conditions related to political rights, civil liberties, freedom of expression, and the competitiveness of positions in the executive and legislative branches of government important qualitative conditions for innovation. Corruption, often measured through an index, is one of the important quantitative indicators.
Inputs into science, technology and innovation systems	Public policies that reflect choices regarding intangible and tangible investments into the generation of knowledge of economic actors determine the quality of the science, technology and innovation systems. Resources for innovation are generated, in part, by inputs related to education and training, government expenditure on research and development and investment in capital equipment. These inputs generate resources for innovation manifesting as a country's knowledge infrastructure which is indicated by population with secondary and tertiary education, percent of researchers in the labour force and scientific papers per capita (as a basis for innovations).
Structural organization of the economy	Measures of industrial structure notably firm size, sector, firm ownership, and firm age influence the propensity to innovate. Large firms have the advantage of larger internally generated finance needed for innovation while some sectors are likely to demand rapid

	Young firms learn faster than old ones thus more likely to innovate. Other than integration of new technologies in capital equipment, traditional sectors (e.g. textile, tobacco, tea, sugar) have fewer technological opportunities. These structural characteristics underpin the balance of exports and imports as an important indicator of the impact of economic structure on innovation.
Outputs of the science, technology and innovation systems	Effectiveness of the STI systems are indicated by its outputs with scientific papers per capita (as knowledge that can be diffused) and number of patents and trademarks registered locally and at the US patent and Trademarks Office as quantitative indicators. Perceptions on the quality of ICT services and diffusion of cellular phones are also important indicators.

The information provided in Tables 1 and 2 bear testimony to the point that the journey from science to markets is complex and far from linear. It is in this context that conceptualizing Malawi's innovation system as comprising circular linkages between the technical system and social system (Figure 2) is important. Thus from the supply side an essential definition of the national system of innovation can be said to be:

> *"...That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies"* (Metcalfe, 1995:38).

From the demand side where firms are central in terms of driving economic growth and development, Malawi's innovation system should be understood as structures that are:

> *'embedded in market processes, processes that determine the payoffs to innovation, that generate the resources for innovation (including customers willing to change behaviour) and that determine how experimental, in a business conjecture sense, a firm, an industry or an economy is'* (Metcalfe and Ramlogan, 2008:440).

The difference between these definitions is in that while the former focuses on supply of knowledge, the latter lays emphasis on the ability of the knowledge to generate wealth that fosters economic growth and development.

10 Locus of control relates to the extent to which individuals feel that they determine their own economic destiny. Where perceptions are that a benefactor controls economic success as would be the case where business opportunities are politicized individuals lose or secede locus of control.

4.0 Understanding the 2010-2011 State of Science and Technology Report (SSTR)

It is important to reflect on the SSTR by considering the meaning of not only what it contains, but also what is missing from it. The sections below exploit the challenges and framework conditions for innovation discussed above to provide some ideas that will contribute to a common understanding of the SSTR.

4.1 STI in the Economy: A Challenged and Framework Conditions Perspective

Chapters 2 to 12 of the SSTR present STI performance indicators in what are considered to be the key economic sectors in the economy. In the section below attention of readers of the Report is drawn to the implications of some of the indicators in the context of the framework conditions for effective and efficient STI systems in an economy.

4.1.2 Market Conditions

The Malawi economy suffered major economic setbacks during the period 2010-2011 which created hard market conditions with respect to most, if not all, of the STI sectors in the SSTR. The overall size of GDP increased to MK687,150 million in 2011 from MK642,816 million in 2010 indicating a nominal growth of 6.9% which is higher than the average growth rate in population (about 2.7%) (Government of Malawi, 2011). Despite improvements in economic growth rates during the period 2006-2009 whose effects spilled over to 2010-2011, Malawi remained a country with one of the lowest GDP per capita in the world. This makes effective demand for goods and services low, especially in the context of high dependence on imports of both intermediate and finished goods amidst a declining real effective exchange rate. There is high likelihood, under these market conditions, that consumers sacrifice quality of goods on the altar of price. There is a direct correlation between demand and innovation. These market conditions negatively impact on innovation since consumers accept what they are given as opposed to demanding products embedding high knowledge intensity. Over time, firms - the locus of innovation, place focus on exploiting current production capabilities while paying little or no attention to exploring new ways of doing things i.e. innovation. These states of affairs are likely to attenuate positive attitudes towards, and openness to, innovation. They are also likely to negatively impact on the interactions between firms and knowledge institutes (research centres and universities) as demand for new knowledge inputs into production processes is capped. The key point is that the policy and institutional framework requires balancing between stability and change since both are necessary pre-conditions for different types of innovation.

4.2.2 *Governance*

4.2.2.1 STI Governance: Building and Organizing National STI Infrastructure

Governments that understand the importance of STI governance invest in scientific and technological research through their national science, technology and innovation infrastructure with the hope of a return on the investment. At the core is the expectation that their economies will be competitive in global markets. It is for this reason that the US's view expressed in 1947 regarding free trade was that free trade is best entered into when a country's industry *'attains the greatest perfection'* and its cities are considered as either *'the greatest commercial emporium'* or *'the greatest manufacturing'* places *'in the world'*. Attaining the greatest perfection in trade entails possession of superior production capabilities based on superior knowledge and skills in individuals and organizations in which they undertake productive activities, firms especially.

In a developing country context, a starting point for achieving this are considerations on how to build and organize the national science, technology and innovation institutional infrastructure. The need for this arises from the obvious fact that most of the knowledge in goods and services traded in global markets (iPods, mobile phones, medicines, motor vehicles, etc.) is generated from scientific and technological research undertaken in developed countries. Understandably, the research is directed towards the demands or anticipated demands of people in those countries with the implication that Malawi and other developing countries need to establish mechanisms for conducting research aimed at solving their own problems and needs. This is why the SSTR gives a comprehensive overview of Malawi's STI infrastructure beginning with a description (in Chapter 1) of the policy, regulatory and institutional and organizational framework for STI.

11 The US matched this ambition with high expenditures on scientific and technological research such that by 1966, its share of global expenditure was 67%.

4.2.2.2 STI Governance: Positioning of National Commission for Science and Technology

Parliament passed the Science and Technology Act (2003) to which the President assented on 7 November, 2003. It was, however, brought into operation on 14 November, 2008 (5 years later!): despite the urgent need to match Malawi's ambition of becoming a technologically-led middle income country by 2020 expressed in the National Vision of 1998 with a robust system for acquisition and application of commercially useful knowledge. The Act created the legal and regulatory framework for building and organizing the national STI infrastructure implied in the National Science and Technology Policy (2002). A reading of both the Policy and Act gives the impression that the National Commission for Science and Technology is the apex body for promoting, financing and coordinating STI in Malawi. To quote, the Act states in section 18(1) that:

> *'The functions of the Commission shall be to advise the Government and other stakeholders on all science and technology matters in order to achieve a science and technology-led development'.*

It further requires, as part of section 3, that;

> *"Every public officer and any authority in Malawi exercising or performing powers, duties or functions in connection with or concerning the commitment of Government in advancing science and technology in Malawi as declared in the National Science and Technology Policy.....shall, in the exercise of his powers or performance of his duties or functions consider and treat the Policy....as ranking paramount in the business of Government...".*

In addition, from the understanding stated in the Policy that: "…*the Science and Technology advisory function will, under this policy, have a strong legal basis and be based in an executive capacity in the Office of the President and Cabinet"*, it is clear that both the Act and Policy intended the Commission to be directly linked to the highest authority - the Presidency. This, if applied, would be consistent with the highly cross-cutting nature of matters related to science, technology and innovation.

12 One possibility is to place STI Policy under OPC which may require review of the Science and Technology Act (2003) with a view to making the Commission a constitutional body such as the Human Rights Commission.

It would create, in OPC, a focal point that would perform the planning and decision-making function on a comprehensive national scale and with the authority derived from that Office. This would, as envisaged in the Policy, constitute a significant restructuring of the science and technology institutional structure. An effective regulatory, legal and institutional framework for STI, appropriately positioned in the public service, can militate against hard institutional failure as much as it can foster interactions between and among actors in Malawi's STI systems. The mechanics of developing this link, if desired, is a matter of organizational re-engineering.

4.2.2.3 Economic Governance: The Business Environment

The corruption indices for Malawi based on Transparency International findings in 2010 and 2011 were 3.4 and 3.0 respectively indicating a declining performance with respect to individual and national integrity. One way corruption manifests itself is through politicization of entrepreneurship in which case exploitation ofentrepreneurial opportunities is not necessarily based on merit. From an innovation perspective, entrepreneurial opportunities relate to 'situations in which new goods, services, raw materials, markets and organizing methods can be introduced through the formation of new means, ends, or means-ends relationships' (Eckhardt and Shane, 2003:336). The role of the entrepreneur is to identify these opportunities and exploit them. Politicization of the opportunities removes the locus of control from the individual thus attenuating entrepreneurial effort and risk-taking behaviour and the innovation that this entails. It also contributes towards sustaining firms that are failing while limiting formation of new ones. Entry and exit of firms in the market is an important condition for economic growth and development.

4.2.3 Inputs into the STI Systems

Education and training, Government Expenditure on Research and Development (GERD); and public and private investment in capital equipment are among the key inputs into national STI systems.

4.2.3.1 Education and Training

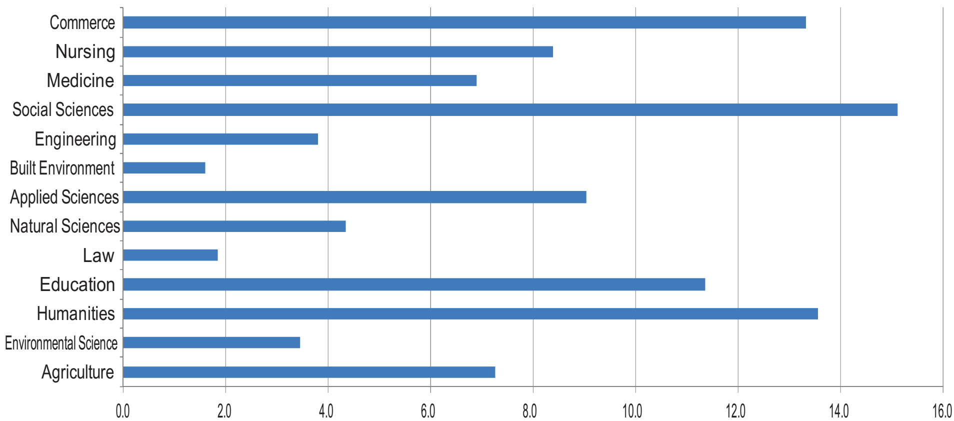
As a matter of observation:

> *"...some poor countries have been rightly criticized for investing too much in higher education, the benefits of which go to small elite. But the criticism has been misinterpreted. What is at issue is not the importance of higher education. The criticism is what is taught, the quality of the education, and how it is financed. Science and Technology are vital. It must be taught at international standards--otherwise it does little good in closing the knowledge gap and it would be better to send students to study*

abroad. And the students should be made to bear as much of the costs as possible, if not now then later, through repaying student loans' (Stiglitz, 1999:317).

There is no denying the fact that primary and secondary education is critical for development. However, tertiary education is the backbone for a science and technology-led development strategy. Using data from University of Malawi, Figure 4 shows the distribution of people who graduated in the various disciplines in 2011.

Figure 4: Proportion of 2011 graduates from University of Malawi by disciplines



	Agriculture	Environmental Science	Humanities	Education	Law	Natural Sciences	Applied Sciences	Built Environment	Engineering	Social Sciences	Medicine	Nursing	Commerce
Series1	7.3	3.5	13.6	11.4	1.8	4.3	9.0	1.6	3.8	15.1	6.9	8.4	13.3

Source: UNIMA

It will be observed that Malawi continues to have a relatively high proportion of graduates in the social sciences, humanities, and commerce. The knowledge and skills sets in these disciplines are important for enabling social change. There is, however, need to balance this with development of national capabilities in hard sciences and engineering; the fields of knowledge that foster technical change. This indicates need to promote not only higher enrolment in hard science and engineering disciplines but also the training of STI human resources to, as Stiglitz (1999) suggests, international standards and putting in place mechanisms to retain the existing qualified human capital. However, the shortage of equipment and teachers undermines this aspect of STI education and training in Malawi while lack of attention to career development prospects of STI human capital fosters brain drain. Chapter 2 of the SSTR fails to give

13 Data from UNESCO Institute for Statistics shows that in 2007 Malawi produced more graduates in humanities (17.8%) than in fields amenable to agriculture (10.7%); and engineering, manufacturing and construction (5.7%).

data on the number of scientists and engineers per million of population which is a very important input indicator of national STI capability. Nonetheless, it is possible to infer from some of the sectors that the STI human capital situation in Malawi is dire.

In health (Chapter 7), the improvements in the output indicators on mortality rates for infants, under-fives, mothers and fatality from malaria were achieved in an operating environment of low human capabilities. Given an under-five population of 2,658,100 for the period 2010-2011 (Statistical Yearbook, 2011) and an average of 7 paediatricians registered with the Medical Council of Malawi for the period (SSTR, Table 6), the ratio of doctor to population in this regard is less than 3 for every 1 million under-five children. The situation is worse with respect to, for example, haematologists and neurologists (also SSTR, Table 6). In agriculture (Chapter 8), despite high post-harvest losses for cereals, there is only one qualified crop storage scientist in the Department of Agricultural Research Services (SSTR, Table 8). Malawi cannot continue to rely on rain-fed agricultural production. Yet there is one irrigation and drainage scientist in the in the Department of Agricultural Research Services (also SSTR, Table 8). Declining human capabilities have been cited as a problem in the genetic resources sector (Chapter 10) and energy and mining (Chapter 10). In the case of climate change and meteorological services (Chapter 11) some meteorological stations had to be closed 'due to (high) staff turnover' emanating from, among other causes, deaths and retirement. Although these statistics relate to the respective STI sub-systems, they are a testament of an economy with low STI capabilities even in critical economic sectors.

In the absence of a Chapter dealing with the broader dimensions of industry as an economic sector, the SSTR has focused largely on indicators driven by public sector organizations as opposed to the private sector. A useful indicator of STI in private enterprises is the number of researchers per 1000 workers in the labour force in which case no statistics are available in any open source/public database. This is most likely not out of omission. In the tobacco and tea sub-sectors sector where private sector research is visible, human capabilities are also constraining progress.

Scientists and technologists, especially those focused on scientific and technological research in both public and private sector research organizations could thus, be an endangered species in Malawi!

4.2.3.2 Gross Expenditure on Research and Development (GERD)

The SSTR has not been able to provide data on how much Government spends on research and development (R&D). This was dealt with by the Department of Science and Technology under the NEPAD-funded African Science Technology and Innovation Indicators Initiative (ASTIII), the report of which is yet to be adopted.

Box 1: What is R&D?

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

The term R&D covers three activities: basic research, applied research and experimental development..

- **Basic research** is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.
- **Applied research** is also original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.
- **Experimental development** is systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed. R&D covers both formal R&D in R&D units and informal or occasional R&D in other units.

There are some activities that are generally excluded as R&D expenditures. These include: routine testing and analysis of materials, components, products, processes, etc; feasibility studies; routine software development; general purpose data collection. The later stages of some clinical drug trials may be more akin to routine testing, particularly in cases where the original research has been done by a drug company or other contractor. Also excluded are expenditures for expansion of university teaching laboratories. The definition, however, includes theoretical investigation of the factors determining regional variations in economic growth which is considered as basic research while investigations performed for the purpose of developing government policy is taken as applied research. Also included are expenditures associated with salaries, services (e.g. testing and trials done in the course of R&D etc.) and consumables (e.g. chemicals) as well as investment in land and equipment - all of which must be in support of R&D activities of the institution and expansion of research laboratories at universities.

The National Science and Technology Policy (2002) requires that Government spends 1% of GDP on research and development. Accepting that Malawi's GDP in 2010 and 2011 was MK642,816 and MK687,150 million respectively (Annual Economic Report, 2012), 1% of these amounts would, accordingly, be MK6.4 and MK6.9 billion. Almost all research organizations featured in the SSTR have cited inadequate funding as a major constraint in their operations. Although hard data has not been generated, it is unlikely that the levels of GERD in Malawi are commensurate with the Policy requirement. Empowering the National Commission for Science and Technology to raise funds as provided for under sections 24 and 32 of the Scienceas provided for under sections 24 and 32 of the Scienceas provided for under sections 24 and 32 of the Science and Technology Act (2003) could alleviate this problem.

4.2.3.3 Investment in capital equipment

Taking off from a low of 18% in 2004, gross capital formation data on the economy rose to a high of 26% by 2006 and remained at that level until a sharp decline to 16% in 2011 (Figure 5). Although highly inclusive, the data in Figure 5 is the best proxy there is for performance of the economy with respect to investment in capital equipment. To the extent that private sector entities invested in new plant and equipment, significant capacity was created during the period 2006-2010 until the sharp decline in 2011, the best evidence yet of the impact of the strains on the economy unleashed in 2010 on account of differences between Malawi and her development partners. This is likely to have constrained application of STI for economic growth and development during the period 2010 - 2011.

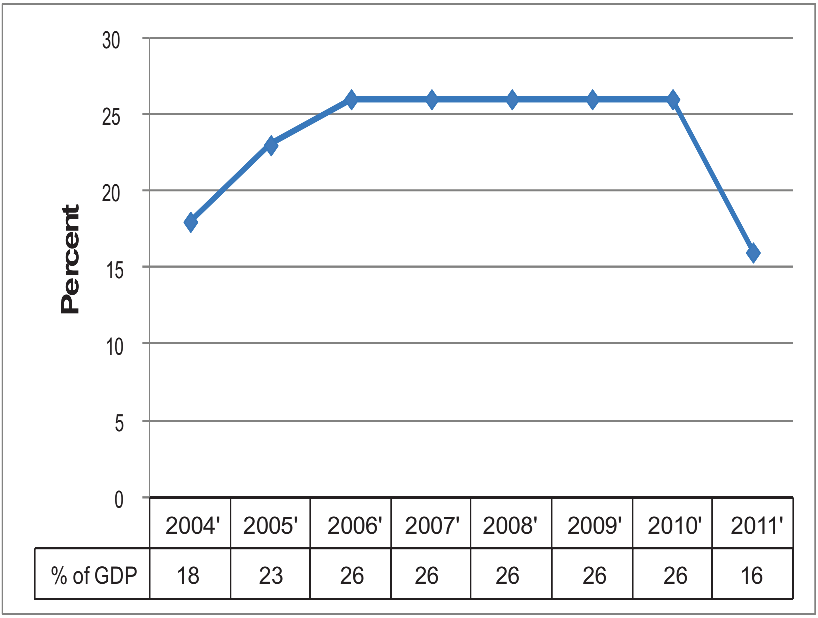
4.2.4 Structural Organization of the Economy

4.2.4.1 Evidence from International Trade

Understanding GDP as a measure of the value of goods and services produced in an economy, the structural orientation of the economy over the five year period to 2011 presented in Figure 6 shows an enduring persistence where services contribute highest towards GDP.

14 Gross capital formation consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress."

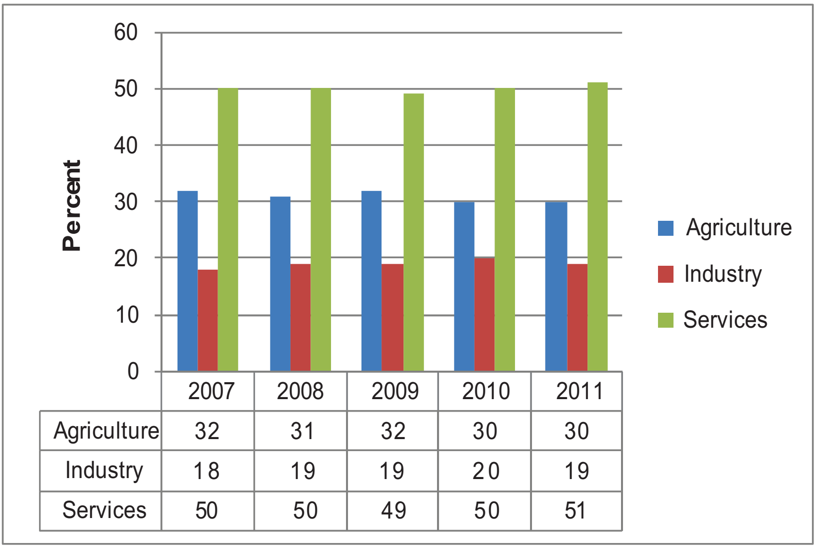
Figure 5: Gross Capital Formation, %GDP (2004 - 2011)



	2004'	2005'	2006'	2007'	2008'	2009'	2010'	2011'
% of GDP	18	23	26	26	26	26	26	16

Source: World Development Indicators

Figure 6: Composition of GDP, 2007-2011



	2007	2008	2009	2010	2011
Agriculture	32	31	32	30	30
Industry	18	19	19	20	19
Services	50	50	49	50	51

Source: World Development Indicators

In the services sector wholesale and retail trade are the dominant sub-sectors with a high proportion of the products being imported into the country as trade statistics from NSO can readily confirm (Table 3). This fact contributes greatly to yet another indicator of framework conditions for innovation: the balance of imports and exports. The well known feature of the Malawi economy where we export primary products while importing processed products is all too visible from Table 3. What Table 3 also shows is that there still is high scope for import substitution industrialization in addition to opportunities for breaking into new products. All this requires STI systems that are efficient and effective with respect to absorption, development and diffusion (transfer) of technology and innovations.

What can support realization of this one may ask - deliberate action that builds on open leadership and promotes entrepreneurship. Entrepreneurial and knowledgeable leaders in both public and private sectors who foster creation of shared visions of the future, adherence to national and firm-level development strategies on a long-term basis; and development of capabilities (human and production capabilities) to realize the strategies. Although agriculture generates the multiplier effects in Malawi's economy, evidence from economic history shows that it is a vibrant manufacturing sector that drives efficient agricultural and service sectors (Reinert, 2007).

Table 3: Exports and Imports, 2010

Broad Economic Category	Exports, MK (million)	Imports, MK (million)
Food and Beverages – Primary	20,634	13,922
Food and Beverages – Processed	12,887	11,677
Industry Suppliers – Primary	109,759	20,406
Industry Suppliers – Processed	5,864	125,980
Fuel and Lubricants – Primary	283	175
Fuels and Lubricants – Processed	87	29,860
Capital Goods (Except transport equipment)	2,741	42,901
Parts and Accessories	548	8,208
Passenger Motor Vehicles	146	7,081
Other Transport Equipment	583	9,667
Transport Equipment Parts and Accessories	346	8,238
Consumer Goods – Durable	420	5,034
Consumer Goods – Semi Durable	3,606	8,285
Consumer Goods – Non Durable	1,068	24,919
Goods not elsewhere Specified	207	9,435
Total	**159,180**	**325,788**

Source: Malawi Trade Report, 2010

4.2.4.2 Industrial Structure Variables: Firm Ownership

Chapter 12 of SSTR that deals with Transport and Construction raises a matter that is consistent with what is known on the role of foreign firms with respect to transfer of knowledge. To quote:

'The industry sees less technology transfer from foreign firms whose services are either imported directly from some bilateral aid projects or through privately executed projects whose clients bring foreign based professionals. This arises from the practice that sees grant construction projects coming with pre-identified construction firms or privately executed projects importing services and having minimal participation of the local human resource'.

Framework conditions for innovation allow an understanding that domestic firms provide better platforms for localized innovation. For example, domestic firms are more likely to depend on the domestic design and engineering capabilities in assembling capital goods thus fostering innovation. This is the context in which a progressive industrial policy is essential for driving STI in Malawi. This is so because knowledge transfer from foreign firms to domestic firms are not 'naturally occurring phenomena but are the reflection of human motivation and imagination' (Metcalfe et al., 2006:17). Internalization of the related knowledge 'involves significant effort, costs and degrees of uncertainty about ultimate success' (Dosi and Nelson, 2010:58). This emphasizes the importance of deliberateness of stakeholders at all levels and the need to provide for related strategies in Malawi's industrial policy.

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15 This relates to the construction industry;

16 In the newly developed countries of East Asia (Korea, Taiwan, Singapore) use of reverse engineering was extensive such that vintage technologies from developed countries provided the basis for eventual existence of new brands of products initially produced a copies of imported ones. WTO rules are now very tight but they do not preclude national effort, guided by industrial policy, to learn from international experience.

4.2.5 Outputs

4.2.5.1 Intellectual Property Rights

Chapter 3 of the SSTR presents an honest assessment of the intellectual property rights (IPR) profile of Malawi where residents have a poor track record with regard to patenting. On an international level, outputs of STI systems are judged by the number of patents residents have registered on the US Patent and Trademarks Office (USPTO) and Malawi has not registered any during the period 2010-2011. At regional level, the African Regional Intellectual Property Office (ARIPO) administers the process of registration of regional patents. Although the related data in Table 1 of the SSTR is not disaggregated, it is unlikely, based on the performance at national level where no patent was registered during the period 2010-2011, that any Malawian patent was registered with ARIPO. Thus, performance in this output indicator appears to correlate with the perceived weakness of Malawi's STI systems. Raising Malawi's profile regarding protection of intellectual property rights is thus a matter of priority. While the review of the IPR policy and legal framework currently underway will contribute to this, effectiveness could be enhanced by integrating exploitation of knowledge contained in patents as an explicit matter of economic policy especially through a progressive industrial policy. In Singapore, the Prime Minister champions exploitation of patents. Indeed, many countries have used a three pronged strategy to foster development: (1) acquiring needed technology prevailing in the developed world, (2) adapting and modifying it in the local environment; and (3) creating related new innovation capabilities with respect to products and processes. These strategies characterize the development of the newly industrialized countries of East Asia and to a good extent, explain their phenomenal development.

4.2.5.2 Scientific Publications

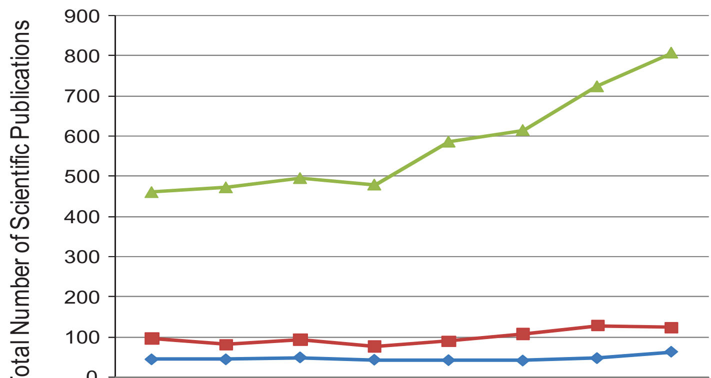
Scientific publications indicate the extent to which STI systems are communicating both within the country and with the international knowledge generation and transfer communities. The SSTR does not attend to this indicator as information on how Malawi performs in his regards is not readily available. Comparative data for the period 2000-2007 shows, however, that Malawi is a laggard in this area. In order to foster knowledge flows through scientific publications, the National Science and Technology Policy (2002) places responsibility on the National Commission for Science and Technology to: (1) encourage local scientists and technologists to publish results of their research work in local journals whose publication would be supported by Government; (2)

develop science disciplines in the university system that would lead to the establishment of journals specific to those disciplines; and (3) establish and strengthen professional associations and societies to enhance discipline-oriented R&D. There is thus need to empower the Commission to perform these functions as much as there is need to ensure that Malawi's research systems are capacitated in terms of human resources and physical infrastructure to generate knowledge that can be published in both local and international journals.

4.2.5.3 Quality of ICT Services

Chapter 4 of the SSTR documents performance indicators with respect to ICT services in Malawi. The extent of diffusion of ICTs is an accepted indicator of the state of STI. Although Malawi is making strides in this area, a lot more needs to be done. For example, the number of internet users doubled from 150,000 in 2010 to 300,000 in 2011 while the number of mobile phones per 100 people rose to 17.13 in 2011 from 16.9 in 2010. These improvements contributed to a marginal increase in Malawi's ICT Index from 1.37 in 2010 to 1.42 in 2011. Despite this, Malawi lost ground on the ICT Development Index which moved down to 144 in 2011 from 143 in 2010 (International Telecommunication Union, 2012). The implication is that while Malawi is improving the quality of its ICT services other countries are doing so faster. This could be the case in many STI sectors of the economy.

Figure 7: Scientific Publications, 2000-2007



	2000	2001	2002	2003	2004	2005	2006	2007
Malawi	44	44	49	43	42	41	47	63
Tanzania	96	81	93	76	89	107	128	123
Malaysia	460	472	495	479	586	615	724	808

Source: World Development Indicators

4.0 Conclusion

It cannot be presumed that Malawians and their representatives in the Legislature easily relate science, technology and innovation with the performance of the economy. This is so because the outputs of science, technology and innovation are so ubiquitous that society in general takes them for granted. Without use of fertilizers Malawi would have had greater annual food deficits as productivity would be extremely low. If chemists, biologists and pharmacologists and other branches of physical and biological sciences had not collaborated to design new forms of HIV drugs, the Global Fund that supports HIV prevention and treatment in Malawi and elsewhere would not have had the visible impact we all have noticed. Production of these drugs requires inputs of process engineers who need the support of economists, accountants and sociologists in order to determine the profitability of their production processes and acceptance on the market-place. This ensures that it makes business sense to produce the drugs in the first place thus, demonstrating the essence of complexity of how knowledge fosters development. It is also the reason why openness to ideas by leaders in public and private sectors is so critical for Malawi. Although there are intentions to foster development and application of science and technology so as to attain the aspirations of Vision 2020, it could be the case that those intentions have not been matched with the necessary resources and leadership (in the context of championing and coalition building) for development of STI capabilities. Existence of such capabilities can foster emergence of collaborative networks aimed at, for example, using indigenous knowledge already existing in Malawi to contribute to generation and application of new knowledge that is essential for enabling development in the social and economic sectors. An initial focus on fostering management and application of knowledge to make our agriculture more efficient in order to sow seeds for migration, in the next 50 years, of labour into the other economic sectors is particularly appealing. Knowledge intensive agriculture has dividends for sustainable and climate smart agriculture. Thus, the STI performance indicators in the Main Report bear testimony of a dearth in national STI capabilities.

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