

Disentangling the STI Concept: Some Theoretical Considerations and Practical Implications for Policy

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Introduction

- Motivation for the paper
 - Use of the concepts as one thing
 - e.g. STI funding, STI education
 - since these are different (though related), it leads to ambiguous policies that are difficult to implement.
- The aim is therefore to disentangle the concepts and draw some lessons for policy.

Defining science, technology and innovation

- **Science**

According to Webster's New Collegiate Dictionary, science is *knowledge covering general truths of the operation of natural laws, esp. as obtained and tested through scientific method.*

- **Technology**

Technology is the making, usage, and knowledge of tools, machines, techniques, or methods of organization in order to solve a problem or perform a specific function (Muller, 2003).

Defining science, technology and innovation Cont..

■ Innovation

- It represents change in technology as brought about by humans.
- Defined as successful creation, development, and marketing of new goods or successful application of new techniques or ways of working that improve the effectiveness of an individual and organization (Archibugi et al., 1994).
- Note that innovation is much broader than just technological

Relationships between Science, Technology and Innovation: The History



- In the early days there was no or very little relationship between science and technology (McClellan & Dorn, 2002).
- Prior to the twentieth century, science and technology have progressed in either partial or full isolation from each other, both intellectually and sociologically.
- Science was then known as natural philosophy, pursued exclusively for intellectual purposes.
- On the other hand, technology served human needs and survived for approximately two million years on its own (Weins, 1999).

Relationships between Science, Technology and Innovation: The History Cont..



- what little innovation and invention occurred was typically done by artisans and craftsmen who knew little of scientific theory (Weins, 1999).
- However, as science and technology both grew and expanded, they came into contact and started influencing each other.
- The obvious connection between science and technology developed during the industrial revolution.
- The connection was largely spurred by the leaps being made by ordinary industrialists and dedicated scientists who made significant discoveries in the realm of science (Murdarasi, 2008).

Relationships between Science, Technology and Innovation: The History Cont..



- To date the connection between science and technology has become clear and accepted, but distorted.
- It is widely understood that science predated technology and that technology to be application of science.
- However, history just told us the opposite, technology antedated science by far.
- And to the contrary, it is technology that gave birth to serious early scientific investigations.
- It was the working of steam engine as a technology that led to the new field of thermodynamics in science.

Relationships between Science, Technology and Innovation: The History Cont..



- In chemistry, the science of polymer that emerged in the twentieth century, in large part resulted from research performed inside industrial laboratories to develop materials that could better fulfill the changing requirement of industry (Nelson., 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.
- In history you can find many such examples.

Relationships between Science, Technology and Innovation: The History Cont..



- However, as both science and technology continued to grow and expanded, scientific discoveries also started to contribute to the development of new technologies.
- Example is the recent discovery of the transistor that led to the whole IT industry.
- And the discovery of recombinant DNA technique (techniques for manipulating the DNA) that led to the whole new biotechnology industry as we know today.
- The relationship between science and technology is therefore symbiotic rather than unidirectional.

Relationships between Science, Technology and Innovation: The History Cont..



How is innovation related to science and technology to form the concept of STI?

- Technological innovation is application of new or improved technologies.
- Can emanate from science or through learning by practice.
- Innovation was formerly tangled with science after the World War II
- The tangling was enhanced by the success of the military science of the War (to the detrimental effect of innovation from practice)

Relationships between Science, Technology and Innovation: The History Cont..



- The success of the military projects, was the demonstration of the fact that scientific projects can be centrally planned and yet highly successful in achieving pre-determined national goals (Guston, 2000, Hollonston, 2009, cited in Diyamett, 2010).
- Later on, as a result of the post war science, in 1945 Vanner Bush – the then director of the US scientific research and development published a report, *Science: the Endless Frontier*, which was incorporated in the American science policy.

Relationships between Science, Technology and Innovation: The History Cont..



- This was also the time the first linear model of innovation on *technology push* was born among scholars of technological innovation.
- According to the model innovation takes place in distinct and sequential phases. Scientific research is considered to be the initiating step and the source of all innovations.
- Essentially innovation was seen as a *linear process* with the key input being R&D, and therefore the thinking that more R&D would yield more innovations beneficial to the market and society at large.

Relationships between Science, Technology and Innovation: The History Cont..



- However, it is now widely recognized that this model is inadequate for depicting the process of innovation which is systemic, with complex feedback loops; and does not necessarily originate from science.
- The early criticisms came from a non-scholarly work - a practical experience from U.S when in the 1950s the director of the US Bureau of Budget, Harold Smith, suggested that Vannevar Bush's *Science: The Endless Frontier*, should be renamed *Science: The Endless Expenditure* (Godin, B. & Lane, J. (ND)

Relationships between Science, Technology and Innovation: The History Cont..



- Reasons for the Harold statement are not clear from the source, but common sense tells that he got tired of allocating money to science because it was not giving dividends to the society in terms of social and economic returns.
- The phenomena is observable even today: the nations that are commit high % of GDP to R&D are not necessarily the most innovative (e.g the Swedish paradox).
- OECD, when criticizing the linear model, lament that the model put too much emphasis on R&D while leaving other inputs to innovation in the background (OECD, 1992).

History is still with us – Sources of Innovation are much broader : STI &DUI Modes of Innovation.



- We learnt from history that technology, for a large part of its history, developed on its own, independent of science.
 - Whatsoever little innovation that happened, was through learning by doing.
 - This to a large extent is still the case even today.
- With close interaction between science and technology, there are now two major modes of innovation: STI & DUI.

History is still with us – Sources of Innovation are much broader : STI &DUI Modes of Innovation Cont..



Defining STI and DUI Modes

- STI (Science, Technology and Innovation) Mode
 - a series of organization action to access for production, transfer and application of scientific knowledge and technology in order to adapt to changes in the environment and build sustainable competitive advantage (Chen, J. 2010).
 - STI-mode of learning relates to science related learning and sees the application of scientific knowledge to produce new technology as the major source of innovation.

History is still with us – Sources of Innovation are much broader :STI &DUI Modes of Innovation Cont..



- **DUI (Doing, Using and Interacting) Mode**
 - a series of organization action to access to production, transfer and application of experience-based knowledge and technology in order to adapt to changes in the environment (Chen, J. 2010).
 - The DUI-mode learning relates to experience-based learning-by-doing, using and interacting.
 - It refers to learning on the jobs as employees face ongoing changes that confront them with new problems, and sees this kind of learning as the major source of innovation.

STI versus DUI Mode of Innovation

- Much Emphasis in terms of Policy is on STI
- But in practice DUI mode of innovation extremely important; and in practice, most widely used
- It has been established that incremental innovations (to which DUI is based) are bread and butter of most successful companies (Council of Canadian Academies, 2009).
- Of course this will ultimately depend on technology classification of sectors. Impact on profitability and easiness to achieve incremental innovation in high tech sectors will be different from those in low tech sectors.

STI versus DUI Mode of Innovation Cont..

- Clear policy bias in favor of STI mode is shown in the system of indicators.
- For instance Trendchart's annual ranking of the innovative performance of EU member nations is based largely on conventional S&T measures such as R&D expenditures, patenting, the share of the population with tertiary education, the weight of S&E graduates in the workforce, ICT expenditures and the importance of venture capital.

STI versus DUI Mode of Innovation Cont..

	Low Tech	High Tech
DUI	1	2
STI	3	4

For Europe concentration is in cell 4, while there are ample avenues for cell 2 and 3 (Lundvall, 2005)

STI versus DUI Mode of Innovation Cont..

- This however is not to argue against R&D or science, but to argue for the right balance between STI and DUI mode of innovation in terms of policy and development of indicators.

STI versus DUI Mode of Innovation Cont..

- Two popular reasons in literature have been offered to explain for the lack focus of policy analysis and indicators capturing the DUI related efforts in innovation (Jensen et al, 2007; Godin & Lane (N.D)).
- The first is political (Godin & Lane; Jensen et al 2007):
 - According to Godin & Lane, historically, merging the R and the D categories, especially in finance, helped the case of candidates looking for symbolic and popular support for public funding of research activity.

STI versus DUI Mode of Innovation Cont..

- The second is complexity.
 - DUI kind of innovation is too complex to measure
 - Jensen et al., 2007, however argues that it can be measured because we know what facilitate DUI mode of innovation. They mention the following:
 - long term linkages with users
 - Interdisciplinary and autonomous project teams
 - problem-solving groups
 - Integration of functions (design, production and marketing)

So what are the policy Implications of all these?

- Policies and indicators that exclusively focus on STI modes of innovation should be balanced with policies and indicators that support DUI mode of innovation.
- This is especially crucial for countries such as Tanzania with very thin or non existent of high tech sectors that are usually supported by STI mode of innovation.
- Because of weak demand, supply side policies that support the STI mode should be balanced with demand side innovation policies, such as public procurement.

So what are the policy Implications of all these? Cont..

- Policies that support DUI mode of innovation include
 - Provision of information brokerage between producers and buyers.
 - Setting standards: enforcing regulatory requirements that allow only products meeting certain standards to enter the market (consumer protection).
 - Other indicators such as project groups and integration of functions that are normally strategic actions at the firm level are not easy to promote through public policies.

So what are the policy Implications of all these? Cont...



- but creating conducive environment for innovation, such as conducive macroeconomic environment; improving international trade; tax policies, reducing cost of doing business and provision of physical infrastructure have elsewhere been found to spur innovative activities.
- Especially when these are coupled with business training, especially on business strategies that include innovation strategies as part of the wider business strategies.

So what are the policy Implications of all these? Cont..

In terms of indicators of human resources:

- emphasis should not only be on number of scientists and engineers, but also those trained in business and technology and innovation management.
- universities and technical colleges should reform their curricular to include problem-based and practical oriented learning as teaching methods
- There has to programs for staff exchange between the university and the industry.

So what are the policy Implications of all these? Cont..

In terms of funding:

- In addition to funding research at the higher learning and other R&D organizations, avenues should be found to directly fund DUI kind of learning that is happening at the industrial firms and farms; either in terms of grants or tax incentives.

Conclusion

- The concept of STI consist of elements that are distinct, although related in a complex way.
- To unpack and understand their relationships for effective policies is extremely important.
- Indicator development and policy should focus on both the STI and DUI mode of innovation.
- Policies focused towards the promotion of STI mode should go hand in hand with supply side policies that instigate demand for innovative products and services.



Thank you very much for your attention