UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

UNCTAD

Training Course on STI Policies

MODULE 1

Innovation, Policy and Development

Participant's Handbook

October 2017 edition

Note

Acknowledgements

The UNCTAD STI Capacity Development Course Module 1 on Innovation, Policy and Development was prepared by UNCTAD economist Dimo Calovski, from the Science, Technology and ICT Branch, Division on Technology and Logistics. Comments and feedback were provided by staff economists Marta Perez-Cuso and Michael Lim. A peer review meeting was held with the participation of the following UNCTAD staff members: Bob Bell, Ermias Biadgleng, Claudia Contreras, Torbjorn Fredriksson , Fiorina Mugione, Mesut Saygali , Christophe Spenneman, Rolf Traeger and Dong Wu. The meeting also benefited from the input of the following external reviewers: Ludo Alcorta , Jean-Eric Aubert, Chux Daniels , Gabriela Dutrenit, Jeong Hyop Lee, Bart Verspagen and Kanchana Wanichkorn. This publication has not been formally edited.

Abbreviations

EU	European Union
FDI	Foreign direct investment
GDP	Gross domestic product
GII	Global innovation index
ICT	Information and communication technology
INSEAD	L'Institut européen d'administration des affaires
IPR	Intellectual property rights
NSI	National system(s) of innovation
OECD	Organisation for Economic Co-operation and Development
OEEC	Organisation for European Economic Co-operation
R&D	Research and development
SME	Small- and medium-sized enterprises
STI	Science, technology and innovation
TRIPs	Agreement on Trade-Related Aspects of Intellectual Property Rights
UN MDGs	United Nations Millennium Development Goals
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

UNCTAD/DTL/STICT/2017/12

UNCTAD STI Capacity Development Course - Module 1

Innovation, Policy and Development

Contents

Preface

The purpose of this Participant's Manual is to provide material that will satisfy three needs. The first is the need to have more detailed content than what can be availed during the in-person presentations during workshops and seminars dedicated to the Module's units. The second is to guide the participant to literature that may be useful for a deeper exploration of the subject of innovation. The third is to provide a set of exercises that can be used to reinforce some of the key ideas presented in this Module.

The units have a certain overlap and common ground. This is intentional. The units are developed so that they can be delivered individually, all together, or mixed and matched in various combinations. This is done in the hope that the Module will be better suited to satisfy diverse workshop and seminar programmes and requirements and in order to better address the specific needs of a particular target audience.

Module 1 on Innovation, Policy and Development is presented in five units.

Unit 1. Introduction

The objective of unit 1 is to develop an understanding of innovation. This is done by relating innovation to concepts such as knowledge, learning, science, technology and innovation policy, and national systems of innovation. The issue is approached from a theoretical and historical perspective and with reference to certain practical challenges that affect developing countries. Firms and entrepreneurship are central elements in this discussion.

1.1 What is innovation?

Innovation is the process of using knowledge and technology to develop, improve, or improve the production or performance, of products, services and processes that have value in terms of commercial impact or social benefit. Innovation is often bundled with science and technology (STI) in discussions on economic policy. Box 1 provides complementary definitions.

The Oslo Manual (OECD/Eurostat, 2005), defines innovation as "the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations."

Our exploration of issues in Module 1 is based on several assumptions at the macro-level about knowledge, learning and innovation processes:

1. They are an integral part of economic development;
2. They are affected by economic, social, cultural, institutional and historical conditions and inheritance;
3. An appreciation of the macroeconomic importance of innovation is vital for policymaking;
4. Innovation is a major driver of growth and diversification;
5. Innovation stimulates trade and investment, and long-term improvements in income and welfare;
6. Active innovation policy is required if developing countries are to catch-up and compete with technologically advanced developed countries.

Box 1: Definitions

Science is a system of knowledge that is concerned with the physical and natural world and its phenomena and works to unveil general truths and the operations of fundamental natural laws. Producing scientific knowledge requires unbiased observations and systematic experimentation using the scientific method.[1]

Technology is the systematic theoretical and practical knowledge and skill used in the process of production or service delivery. Technology is not a finished product or service. Technology includes the entrepreneurial expertise and professional know-how needed to deliver products and services (UNCTAD; 1985, 2014a).

Inventions are new or novel practical applications of knowledge, technology and ideas that come from experience, scientific enquiry and research and development.

Innovation is the process of using knowledge and technology to

- develop,
- improve, or
- improve the production or performance

of products, services and processes that have value in terms of commercial impact or social benefit.

The Oslo Manual (OECD/Eurostat, 2005), define innovation as "the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations."

[1] Encyclopedia Britannica; https://global.britannica.com/topic/science. Merriam-Webster, https://www.merriam-webster.com/dictionary/science.

In practice, innovation mostly happens in firms or institutions. Innovation is an important and often primary component of entrepreneurial activity. We observe innovation as a search for new or more efficient combinations of resources to better satisfy existing consumer demand or to address unmet or new needs. Therefore, innovation includes the introduction of new products, services and processes, as well as innovations that are novel in a particular market. Innovation includes new or novel processes used by firms and institutions in producing goods and providing services.

Innovation happens by pushing forward the frontiers of technology. Innovation also happens when firms learn to employ knowledge and technologies that are already used elsewhere. This is often the case in many developing countries. From a development perspective, technology acquisition, imitation and adaptation are key innovative processes and require more government policy attention than scientific research.

The term *innovation* is often used in a similar context as *invention* or *creation*. However, *innovation* has become the current catchword and is replacing *invention* in common use.[2] Historically, *invention* has been discussed as a central factor in industrialization and the strong economic growth that resulted in todays' developed economies. The change in focus from invention to innovation was sparked by the discussions of Schumpeter (Godin, 2008). Schumpeter proposed that innovation was an economic decision: a firm applying an invention in its products or production process. Invention on its own, on the other hand, was an act of human creativity and was of secondary importance for economic decision-making (Schumpeter, 1939).

The understanding of innovation itself has changed in the last three decades. Policymakers realize that innovation is increasingly less predictable in today’s highly competitive and complex economies. As a result, policy focus has shifted from managing innovation to managing an environment where innovations can emerge and have impact. This change of perspective is witnessed in the advance of our understanding of the need for STI policy and the development National Systems of Innovation theory and practice.[3]

1.2 Why do countries need STI policy?

The term STI policy is used in this module to describe the sum of all policies that aim to improve the contribution of STI processes and activities to economic and social development. This would include:

- Macroeconomic policy and in particular fiscal measures that are aimed at promoting R&D activities and increasing technological absorptive capacities in firms and institutions,
- Regulatory measures such as evolving technological and environmental standards,
- The STI-related work of various government departments and their procurement activities,
- Policies on education and human capacity development,
- Industrial policy,
- Intellectual property policy,
- Sector specific policies such as those promoting life sciences industries or sustainable technologies,
- Policies in support of ICTs and information society development,
- Policies that create business *and* consumer friendly markets and sectors, and

[2] A casual online search returns twice as many hits for innovation than invention. A search on google.com on 5 May 2015 returned 398 million hits for innovation but only 207 million hits for invention.
[3] For an overview of NSI theory, see: Lundvall B-A, Eds. (2010).

- Policies that aim to support the development of networks and interactions among government, academic and business STI stakeholders.

In the first half of the twentieth century STI became an area of explicit and active policymaking. A strong concern about market failures – that the unhindered interactions of firms and consumers in markets would under-produce and under-consume technology relative to some projected social optimum – provided the justification for financing R&D as government policy. STI policy tended to focus on investment in research and development (R&D) and on efforts to achieve an efficient transformation of subsidized R&D into commercial products and services.

At the time, three sources of market failures were recognized: externalities, uncertainty and indivisibilities.

Externalities. The main reason for the existence of externalities in STI was the difficulty to exclusively own the outcome of one's research investment. Knowledge developed through R&D in one firm will spread to others in informal communication as employees change jobs, during communication with and among entrepreneurs and investors, at conferences, and through publications in media or academic journals. Because competitors can benefit from such spillovers without paying, firms will hesitate to invest in R&D and technological progress will therefore be restrained.

Uncertainty. Uncertainty, which is a natural part of any innovation process, results in a market failure because it produces information asymmetries. Uneven information will result in difficulties in developing a common view between firms and financiers about the risks and returns of an innovative business proposition. This may result in under-investment in R&D as firms fail to access and secure external financing. Understanding uncertainty in innovation is important for good policymaking and will be discussed in the section 1.3.

Indivisibility. As for the problem of indivisibility, economies of scale are often needed to justify investment in R&D. However, there may be questions as to the required scale of production for commercializing an innovation and whether individual firms have the appropriate financial capacity. This acts as a disincentive mainly when there are doubts that production and sales volumes are insufficient to justify the R&D expenses, or when firms and financiers may be too small or unwilling to support innovation with investment in sufficiently large production facilities.

1.3 Innovation risk and uncertainty

While all economic activity is more or less risky, entrepreneurial activity with a dominant innovation component is firmly planted in the realm of uncertainty. For many people, the distinction between risk and uncertainty is semantic or, at best, a question of scale or size. However, there is a fundamental difference between risk and uncertainty and policymakers and entrepreneurs who can assimilate this distinction stand a better chance of managing STI policy and practice.

What brings about much confusion, as well as a variety of insight, is that many economic actors have their own definitions of risk, while things uncertain are sometimes confounded with things unknown. For example, the insurance sector deals with pure risks – risks that have no upside. A broader category would be speculative risks: these may have an upside as well as a downside. A financial institution may understand the concept of risk as the standard deviation of an outcome around its historical average – financial assets that are volatile, that exhibit large deviations around their average performance, are considered risky. Business and entrepreneurial risks have a large component of uncertainty as firms operate in complex and dynamic environments.

More broadly and at the level of everyday personal experiences, people will equate risk or uncertainty with the unknown. This is because it is practically unfeasible to know the statistical probabilities and distributions of the multitude of life events, nor the averages and standard deviations that we generate in living those events. People take decisions and adjust whenever possible with feedback, but without profound statistical analysis. Such decisions are often loaded with problems of framing, wishful thinking, groupthink and cultural and cognitive biases.[4]

Knight (1921) distinguished between risk and uncertainty by proposing that risk is a measurable quantity: if we can determine the probability of an event with a known accuracy – and this implies that we know the distribution of the event – we are dealing with risk. Risks can be managed: they can be reserved for, hedged against or insured, i.e. transferred to a willing party for a price-premium. Uncertainty is a fundamentally different species. An event is uncertain when we cannot determine its distribution, observe the process that generates it, or assess statistical averages and standard deviations. This is often the case with business and innovation where uncertainty is compounded by the dynamics of an ever-changing economic and social environment. Knight proposes that if a phenomenon can be assessed statistically with confidence, it is not uncertain.[5]

Knight also suggests that in business, uncertainty is the source of profit. Innovative businesses, being more uncertain than mundane ventures, promise greater returns as well as a larger chance of failure. Uncertainty in innovation is dynamic and it can have multiple sources. Haragadon (2012) designates four sources of uncertainty for firms-innovators which are described below.

Policy uncertainty. Uncertainty is generated around future decisions as to what public policies will be enacted, and how they will be implemented. Such policies can take many forms, from standards regulations to taxes and subsidies. Changing the regulatory environment of customers or suppliers, or changes in support to subsidized industries or state-owned companies can increase uncertainty. Changing regulations for FDI and joint venture can have important effects as well. This aspect is clearly a responsibility of policymakers and it has been UNCTAD's recommendation during several national policy review processes that policymakers need to clearly articulate future policy moves in order to reduce uncertainty for firms and innovators.

Market uncertainty. Another major source of uncertainty is market acceptance. Customer preferences change as competition emerges from within or outside an industry. Preferences change with changing lifestyle perspectives often due to evolving age and demographics. Purchase decisions for a single product can be enhanced or exacerbated in concert with other purchases of complementary or competing goods and will on occasion be subject to changing public policy and regulation or public perception on issues such as safety, health or environmental concerns.

Business uncertainty. A key concern is the future profitability and sustainability of an innovation. Firms and entrepreneurs will sometimes tread untested waters and attempt to develop new markets. As first movers they will be the first to garner experience and assess feedback from consumers, suppliers and partners. As disrupters, they will attempt to displace established and entrenched competitors with mature supply chains, appropriate production and technology scales and extensive knowledge of the market and the regulatory environment. Profitability is a fickle component and changes in market conditions – for example for a key component supplier or conditions of finance – can change everything.

[4] For a detailed discussion of cognitive biases, see Kahneman (2011).

[5] Knight asserts that uncertainty is distinct from risk, whereby risk is a measurable quantity defined as how much does an outcome vary around its average. With uncertainty there are problems in measurement because the process that produces uncertain outcomes is not observable, ever-changing, complex and chaotic, and its statistical distribution is unknown. For example, future outcomes of a roulette game are risky while future economic developments are uncertain.

Technology uncertainty. Finally, technology uncertainty presents disincentives for firms to move out of the R&D stage and into prototyping, commercialization and diffusion. One general concern is whether production can technically scale to commercial volumes outside the R&D facilities. Will the factory be able to produce according to expected quality criteria as well as with respect to the economics of the production process in terms of speed, energy used, waste and spoilage generated? There will also be some uncertainty as to how the product interacts, at a technical level, with other components or products that define its final use.

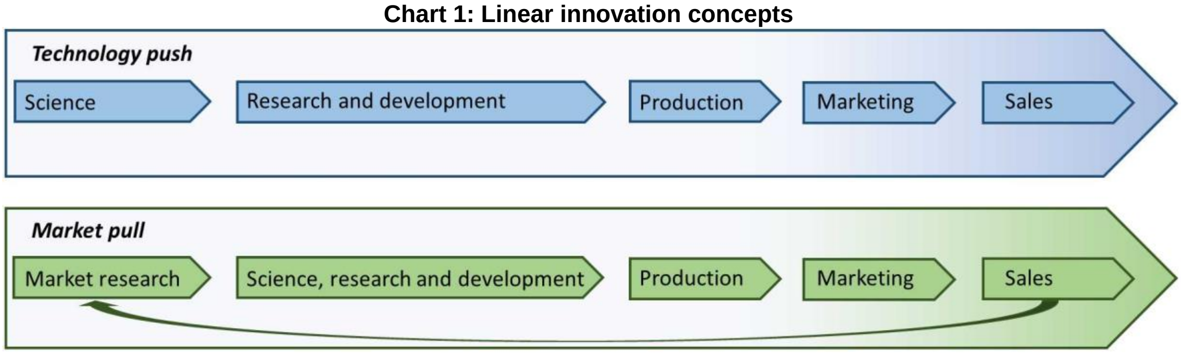
From a policy perspective Knight suggested that distinguishing between risk and uncertainty is important as policymakers could be prone to setting up facilities decreasing risk – such as export finance and insurance mechanisms, credit financing at privileged rates and various subsidies and tax facilities – thinking they are reducing uncertainty. However, policies that reduce risk do not necessarily remove uncertainty. Risk-reduction policies can however increase uncertainty if and when concerns are raised about their sustainability or necessity, and their removal is considered as policymakers shift priorities.

1.4 Linear innovation and innovation systems

Linear innovation models

Investing mainly in science and some R&D and trusting that this spurs the development of applied technologies after which they enter commercialization is today called a "linear model" of innovation. Such practice could be observed, with some variety, in many developed countries until the 1960s. A frequently referenced expression of linear STI thinking can be found in Vannevar Bush's 1945 report *Science The Endless Frontier*.[6] Linear innovation was sometimes described as a *technology push* models because it was assumed that markets and consumers where eager to embrace almost any innovation that could be generated. An alternative linear innovation model is that of *market pull*. This process was observed in the 1970s and replaced science with market research as the starting point for innovation. Inevitably, sales information feeds back into market research. Chart 1 describes these linear innovation concepts.

Chart 1: Linear innovation concepts



Linear models of innovation are largely retrospective academic assessments of innovation policy practice. They were not developed to be implemented as a policy during the related historic periods.[7]

[6] *Science the Endless Frontier* is a report on directions for science policy presented to the President of the United States in 1945 by then Director of the Office of Scientific Research and Development, Vannevar Bush. Bush proposes, in no uncertain terms, that *"… without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world."*

[7] For example, Nathan Rosenberg, a well-known economist specializing in the history of technology, does not use the term linear innovation in any of his research papers from published from in 1960s and 1970s as compiled in his "Perspectives on Technology", while Christopher Freeman, the founder and first director of Science Policy Research Unit at the University of Sussex and an eminent academic in innovation studies introduces a discussion of linear innovation only in the third 1997

The rationale for proposing simple linear models was the observation of how significant increases in spending on scientific research and R&D in the decades following the Second World War resulted in strong economic growth, especially in the United States.

In reality, innovation is not linear. Innovation processes are complex and evolve many feedback loops of varying strength involving a greater scope of STI stakeholders than just scientists and industrialists. However, criticizing the linear model allowed policymakers to develop a more organic, complex and embracing theory of *national systems of innovation* (Edgerton, 2004). This meant moving away from a linear understanding of innovation in which public funding of R&D is seen as the main or only policy that matters.

Unfortunately, even today, a linear innovation mind-frame is frequently found among many policymakers and STI stakeholders. The idea that an improved funding of science and R&D is the solution to development challenges often translates into policies that are necessary but remarkably insufficient.[8] A lack of capacity and capability among firms and institutions to absorb technology together with a gamut of micro- and macro-economic disincentives will make spending on R&D ineffective. Without deliberate linkages to productive sectors in services and industry and policies that govern and support them, research outcomes will vary in relevance and effectiveness, and funding may be revoked during periods of economic hardship.

National systems of innovation

The concept of non-linear *national systems of innovation* (NSI) surfaced in the late 1980s and 1990s with the realization that, while innovation takes place mainly in firms, firms do not innovate in isolation. Firms interact with other firms and institutions, and with the general public. They develop and exchange knowledge and technologies needed to innovate in an environment. In increasingly competitive sectors and industries, learning becomes a permanent activity. The sum of firms' technological capabilities, interactions and knowledge flows, among themselves and with institutions and people in their national environment, is referred to as the *national system of innovation*.[9] The consideration of STI policies through an NSI perspective and its historic origins and evolution as a policy practice will be discussed in more detail in unit 5 of this module.

NSI are often fairly weak in many developing and least developed countries and can lack explicit or strong policy support in some developed economies. An NSI exists regardless of the intensity of knowledge and technology flows and interactions, or the formal support that these interactions receive from government policy. The nature of a particular NSI will depend on the interplay of many economic, historic and cultural factors. This means that the characteristics of any NSI are dynamic and permanently changing, yet affected by diverse policy decisions and activities. The relationship between STI policy and an NSI is symbiotic and mutually reinforcing. An NSI can be seen as a framework for implementing *science, technology and innovation* (STI) policy.

NSI theory suggest that STI processes are a systemic and endogenous phenomenon: innovation occurs as a result of the interaction of knowledge, institutions and firms. Variations in the innovative performance of different countries are mainly due to differences in the nature and intensity of these interactions and how they affect the creation, transfer and use of knowledge. This is in stark contrast

edition of his "The economics of industrial innovation" while giving no mention in previous first (1974) and second editions (1982).

[8] This assessment is based interviews and discussions conducted between UNCTAD experts and policymakers in the conduct of technical cooperation projects and conduct of STI policy reviews in ten countries.

[9] Firms, government and academic and educational institutions, their capabilities and competencies, together with relevant aspects of the regulatory and legal system, constitute the core NSI. More recently, civil society, the general public and environmental and sustainability concerns and interests are being considered as elements of an NSI environment.

to traditional economic theory which considered technology as an external, unexplained occurrence and which will be discussed in unit 2 of this module. NSI theory proposes that innovation is a natural component of economic activity and suggest that the traditional concepts of market failure are important but insufficient as a rationale for government policy and intervention (Freeman, 1987; Lundvall, 1992; Nelson 1993). Since interactions that result in and cause innovation can take place through market and non-market mechanisms, the justification for policy action is not merely to respond to market failures but also to systemic and institutional failures, such as underdeveloped infrastructure, institutions, networks, regulations and coordination mechanisms, as well as path-dependencies and lock-in effects.

A key issue is that NSI theory recognizes the importance of tacit knowledge. In Polanyi's words (1966) an important problem is that *"...we can know more than we can tell."* Knowledge that evades codification – being translated into language or defined as a process – is referred to as tacit knowledge. Because it is difficult to codify, it is nearly impossible to transfer formally. It follows that it is difficult to acquire tacit knowledge by simply buying equipment, education or training. Transferring tacit knowledge on a commercial basis by buying consultancy services or hiring individuals with known and well-developed competencies can be challenging as well. It therefore remains largely outside of the purview of policies that address markets and market failures. Capturing and defusing tacit knowledge happens over time through practice and interactions in working environments. Such processes are not easily replicable and tend to develop organically.

The capacity of a firm, an economic sector or an economy to innovate can be seen as the sum of its capacity to acquire, apply and adapt both formal and tacit knowledge. Lacking one or the other will increase the risk of failed development policies. The NSI approach highlights the importance of enabling learning interactions that include tacit knowledge creation and diffusion. Policies that ignore the importance of tacit knowledge and promote capacity and technology development only through formal knowledge processes, such as increasing the number of tertiary graduates or funding for academic research, miss out on developing and supporting interactions among a broader set of stakeholders and risk suboptimal results and returns on public investment. This, in consequence, poses a general threat to development as public politics may turn to see investment in education and research as wasteful or ineffective at best.

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Selected reading materials

1. A Framework for STI. Chapters 1 and 2, UNCTAD/DTL/STICT/2011/7.
2. Innovation: The History of a Buzzword. The Atlantic, 20 June 2013.
3. Risk, Uncertainty, and the Challenge of Sustainable Innovation, Hargadon (2012).
4. National Systems of Innovation, 1. Introduction; Ludvall (2010).
5. Systems of Innovation Approaches - Their Emergence and Characteristics, Edquist (1997).

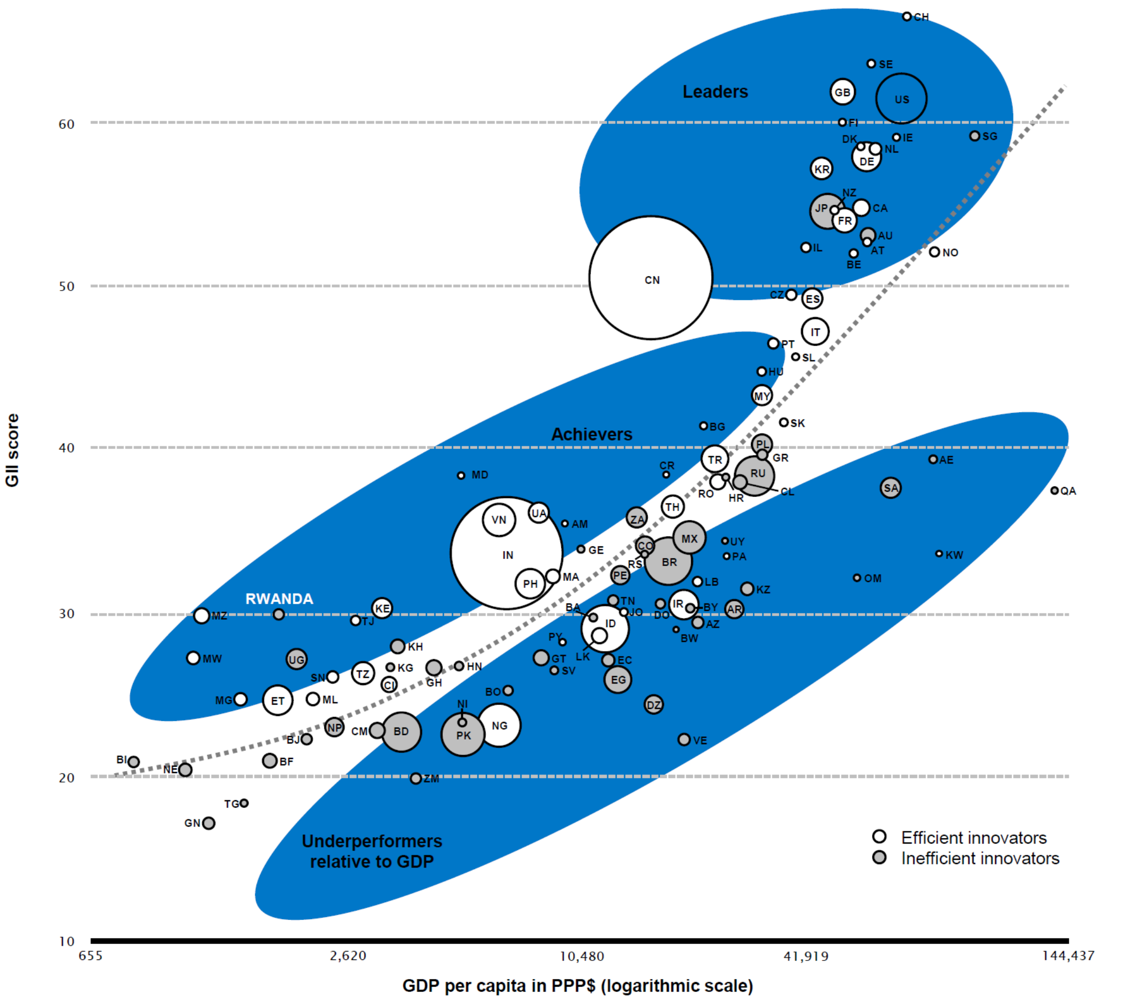
Unit 2. Innovation policy in a development context

2.1 Underperformance on innovation

Developing countries are underperforming on their innovation and economic potential in spite of an improvement in a number of favorable conditions. Access to knowledge has greatly improved during the last two decades. Transport and communication costs are decreasing. Global markets can provide sufficient demand to overcome limited domestic markets. However, UNCTAD (2007) cautions that unless developing countries implement policies for technological catch-up with developed economies, they will face deepening marginalization in the global economy. The focus of policy should be on enabling technological learning and innovation by domestic firms. Conventionally understood technological transfer and pure scientific research are important but secondary considerations. Trade liberalization without technological learning and innovation will increase economic marginalization.

Regardless of ubiquitous knowledge and technological opportunities, there are only a handful of developing countries that have become developed. What is clear is that those that have, such as Japan, the Republic of Korea or Singapore, have resolved the challenges of financing and acquisition of technology and creating incentives for innovation. Chart 2 presents a mapping of innovation performance among a number of countries using the Global Innovation Index.

Chart 2: GII scores and GDP per capita in PPP$*



Source: The Global Innovation Index 2016 (Cornell University, INSEAD, and WIPO; 2016).
* Note: Bubbles sized by population; country codes are ISO 3166.

Historical experience suggests that policies that promote technological learning and innovation can stimulate structural change, improve firm competitiveness and create growth and jobs. Recognizing this, there is a growing interest among developing countries in defining their innovation policy within their overall strategic development policies and priorities. The success of several developing countries in technological and economic catch-up has renewed interest in technology and innovation. However, the reality is that STI policies are still on the periphery of many countries' development strategies.

2.2 Weak national systems of innovation

The most common problem is a fragmented and weak national system of innovation. Linkages among STI stakeholders – firms, academics, government and civil society – are few, and nodes of collaboration and coordination are regularly underperforming. The technological capabilities of many firms are underdeveloped, innovation infrastructure is lacking and pro-innovation incentives are weak.[10] When this is the case, establishing innovation as a primary development concern and connecting it to other development policies should be a top priority. However, innovation is more than a question of technology strategy: STI policy is unavoidably political by nature and therefore requires significant leadership competencies. STI policy involves political decisions because stakeholder interactions and the set of incentives and disincentives that they face are complex, dynamic, sometimes contradictory, and highly country- or location-specific. An effective policy will need to address all STI stakeholders.

Policymakers in developing countries should recognize that technological change and the implementation of innovation policy can be very different when compared to developed market economies. Policymakers need to establish a robust understanding of the key strengths and weaknesses of their own NSI and identify strategic priorities for development. It follows that policy experimentation and learning should be encouraged and policy outcomes must be assessed and used to correct and adjust implementation. However, measuring innovation in developing countries presents material and conceptual issues. Policymakers may find it difficult to develop evidence-based arguments for STI policies if data is scarce or difficult to amass. Broader international experiences should therefore be considered as sources of insight, and innovation experiences in other developing countries should be used in search of replicable lessons and wisdom.[11]

A successful STI policy requires the coordinated management of large number of explicit and implicit policies. Explicit policies can address, for example, education, technology and innovation parks and business incubators, technological support services, intellectual property, or transfer of technology through foreign direct investment or trade. The notion of implicit STI policy instruments refers to the impact that policies can have on the development of technological capabilities or the emergence of learning linkages in the economy. Examples of such policies are general trade policies, public procurement, taxation, infrastructure investment (energy, transport, telecoms, etc.), competition policy, consumer protection, or direct and indirect financial support to enterprises. The complexity of the policy challenge is underscored by the need to address both market and systemic failures, as well as to combine horizontal policies (education and training, access to finance or knowledge dissemination) and vertical ones (support to specific industries or sectors and/or technologies).

[10] Innovation infrastructure can include many elements ranging from a functioning intellectual property system, to technical facilities for prototyping, institutional arrangements for conducting joint public-private research and development to funding mechanisms such as venture capital funds.

[11] One such source is the UNCTAD STIP Review programme which is at the core of UNCTAD's technical cooperation work in the field of STI. It draws on decades of accumulated policy research and advocacy in science and technology for development. It also takes advantage of UNCTAD's position as the institutional home of the United Nations Commission on Science and Technology for Development to share best practices identified through the implementation of STIP Reviews and to promote cooperation in STI among development partners. The OECD Reviews of Innovation Policy are another source even if their subjects are often higher income countries and mainly OECD members.

The inherent complexity of a systems-based approach to STI policies, expressed as the need for a highly sophisticated understanding of policy interactions and for strong coordination and collaboration among Ministries, agencies and other public and private actors, can represent a strain for the human and institutional resources of many developing countries. Often, innovation policy is entrusted to ministries of science and technology which, given their focus on science and research, may help perpetuate a linear, research driven approach to innovation while shying away from developing collaboration with productive sectors and industries. Given the low levels of investment in R&D in many developing countries, such ministries may lack the political weight that would be needed to unite STI stakeholders by focusing on policies linking innovation to production, competitiveness and development. Budgets for supporting STI policy can be extremely low and sometimes are nonexistent.

Economic policy insights on STI using an NSI policy framework need to be embraced with an open mind. This may require revisiting prior knowledge, changing perspectives, questioning common assumptions and relearning first principles. All too often there is an exaggerated emphasis on a single policy problem and solution – such as the number of university graduates or financing R&D – tied to a conviction that if that particular issue is not addressed all else is in vain. Responding by enlarging the scope of consideration to explore other STI challenges piecemeal is a necessary but insufficient move towards developing and implementing a successful STI policy.

Finally, it is imperative that policymakers working in a development context profoundly appreciate and embrace the notion that innovation is incomplete without commercialization. Firms succeed or fail by their ability to successfully bring innovations to market. Successful commercialization means that entrepreneurial activity has led to economic development and growth (Datta *et al.*, 2013). However, this is a complex process that may be understood with varying precision, using a mix of any number of scientific and academic disciplines. Commercialization is a difficult process to systematize given that each innovative venture engages a different set of unknowns and uncertainties. What is clear is that the availability of competent innovation partners (e.g. other firms, academia or business support institutions, etc.) can reduce the uncertainty of commercialization. To this end, supporting a national system of innovation through positive government policy is vital.

2.3 Absorptive capacities

A major consideration for STI policy in developing countries is that innovation occurs mostly through the adoption, absorption and adaptation of imported technology. From a development perspective, innovation policy is thus primarily concerned with encouraging and enabling technological and economic discovery and the process of learning, and creating and developing the necessary human and institutional competencies and technological capacities. This is often referred to as the creation of absorptive capacities.

Absorptive capacity is determined by the availability of a wide range of skills, expertise and infrastructure. This includes the ability to assess innovation potential, learn, and diffuse knowledge at the level of the individual and as a firm or organization. STI policies to strengthen absorptive capacity can be organized along four mainstays: (a) human resources development; (b) supporting investment by firms in learning and innovation; (c) stimulating the emergence of linkages among firms and with universities, research institutions and technology intermediaries; and (d) strengthening support for economic discovery – assessing the commercial impact of a potential innovation.

In addition to the above, several elements of STI policymaking are particularly relevant for developing absorptive capacities. These include, for example, the optimization of trade and investment links with foreign sources of technology and managing the relationship between technology imports and the generation of national technological capacities. The challenges and opportunities to innovation presented by the intellectual property regime may require rebalancing through direct financial support or fiscal measures. Furthermore, many countries may need to enhance innovation in agriculture while dealing with rural underemployment and a high demand for off-farm jobs. Often, developing countries have a significant informal economy whose innovation processes also need to be addressed through policies supporting inclusive innovation, social innovation, and sustainability challenges. Finally, STI and development policy will need to consider the social consequences of rapid structural change induced by technological catch-up and innovation as parts of society remain economically and technologically marginalized.

2.4 Structure and strength of incentives

A major policy problem is the structure and strength of incentives. In many developing countries these are too weak to drive innovation. The effectiveness of STI policy is largely defined by how it incentivizes and supports learning interactions and knowledge flows. Incentives and public policy work to support cooperation between knowledge generation and diffusion institutions[12] and firms and organizations that need knowledge and competencies to innovate.

Market incentives are weak because markets are small and consumers are poor with limited or no access to credit. If markets are limited in their ability to pay, Governments may choose to provide incentives that would focus innovation on alleviating poverty, often referred to as social or inclusive innovation. Governments may also consider using public procurement to stimulate technological upgrading and innovation. They may act as leaders in innovation through, for example, improving the provision of online administrative services, or eGovernance.

Apart from insufficient market incentives, there are a number of institutional issues that require attention, among which insufficient incentives for cooperation and for horizontal communication. This leads to insufficient flows of tacit knowledge. For example, UNCTAD STI policy reviews document cases of such lack of cooperation either between public institutions or between public and private entities and firms. Disincentives may arise from concerns that decision making processes can get bogged down in discussions or can result in obligations of reporting and performance to stakeholders with marginal roles in implementation.

Disincentives to horizontal communication among staff working in large firms and government are not uncommon. The idea that coordinating information flows at the highest levels of corporate or government decision-making or management improves cooperation and reduces uncertainty and risk in daily operations is flawed if a firm or institution needs to stimulate innovation. The remedy is to stimulate horizontal communication as a key vector for the transfer of tacit knowledge and exploration of innovation opportunities. Disincentives to horizontal communication usually appear as perceptions of falling into disfavor with supervisors or high-level management. Political leadership can directly act to remedy this in government and public institutions. However, private firms may not be as easy to reach with neither the message nor an appropriate policy. In that case, policy should focus on awareness-building and supporting the development of STI clusters, such as technology parks and business incubators, which aim to provide an environment for increased interaction.

A typical example would be a lack of participation of industry representatives in decisions on the number of university and vocational education enrollments per discipline or expertise. As long as the success of tertiary education is measured in absolute terms and as long as there is demand for enrollment, actual employment opportunities will be at best only a secondary consideration. Another example is developing guidelines on interaction with external entities. A typical case would be guidelines on producing and managing intellectual property using public funding for traditional knowledge, heritage, biodiversity, etc. If the entity in charge, say a museum, has only preservation as

[12] Such as universities, research institutes, extension services, vocational education, etc.

its main objective, left on its own it may develop IPR guidelines that can be unbalanced. Allowing firms and civil society to participate in defining IPR policy and thereby introduce other objectives, such as facilitating broad public access or commercialization, would enlarge the scope for potential innovation. However, this may put the museum management out of their competency, knowledge or institutional culture, and there may be resistance to allow such a process.

More generally, intellectual property rights (IPR) are often discussed as both an incentive and disincentive to innovation, in particular in the context of development and LDCs. As an incentive, IPRs act to reward the commercialization of innovation which subsequently reinforces growth and development. They also help to improve the disclosure of new knowledge and technical solutions in the sense that if IPR protection may be lacking, many improvements and discoveries would be kept undisclosed as trade secrets.

From a national development perspective, it is an inconvenient truth that many developed countries never had to face such stringent IPR requirements during their own phases of industrial development as developing countries have to do now, and therefore a more balanced policy perspective is needed. Unfortunately, the policy space for IPR is greatly reduced as most countries are parties to the WIPO and WTO TRIPS conventions. At a national level, IPR policies need to be relevant to the actual industries and services that constitute the economy, as well as to budding innovative firms and sectors. Aside from technical capacity and funding needed to implement a national IPR regime beyond just having internationally compatible legislation, policymakers also a need to assess the size of the market for IPR among the research and business community and build awareness of actual cost implications, as these are not insignificant. A dedicated module of this course will look in more detail into the IPR issue, in particularly within the context of technology transfer.

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Selected reading materials

1. Chapter 4. Innovation systems and absorptive capacities, in Transfer of technology and knowledge-sharing for development (UNCTAD, 2014a)

2. Introduction: Why Technological Learning and Innovation Matter for LDCs; in UNCTAD (2007). The Least Developed Countries Report.

Unit 3. The economics of innovation

The goal of unit 3 is to deepen the discussion in unit 2 by looking at the relationship between innovation and STI policy, development policy and economic theory. The discussion concludes by considering several issues that present serious challenges for developing country policymakers.

3.1 Conditions for growth and innovation

Since the 1600s the world has witnessed increasingly divergent economic growth. Some countries and regions grew steadily, others accelerated, while still others stagnated in comparison. This is described by the growth spread in GDP per capita (see table 1.) which has increased from 3:1 to 25:1 during the last 200 years. Before the end of the 1800s, the United States had surpassed Europe in GDP per capita. After the Second World War, Europe and Japan made remarkable progress.

Table 1: Per capita GDP and Interregional Spread (US dollars)[13]

	Year								
	1000	**1500**	**1820**	**1870**	**1913**	**1950**	**1973**	**1998**	**2012**
Western Offshoots	400	400	1,201	2,431	5,257	9,288	16,172	26,146	52,406
Japan	425	500	669	737	1,387	1,926	11,439	20,413	46,679
Western Europe	400	774	1,232	1,974	3,473	4,594	11,534	17,921	34,115
Eastern Europe & former USSR	400	483	667	917	1,501	2,601	5,729	4,354	10,460
Latin America	400	416	665	698	1,511	2,554	4,531	5,795	9,067
Asia (excluding Japan)	450	572	575	543	640	635	1,231	2,936	5,326
Africa	416	400	418	444	585	852	1,365	1,368	2,061
World	*435*	*565*	*667*	*867*	*1,510*	*2,114*	*4,104*	*5,709*	*10,442*
Interregional Spreads	**1.1:1**	**2:1**	**3:1**	**5:1**	**9:1**	**15:1**	**13:1**	**19:1**	**25:1**

Source: OECD, 2006; data for 2012: World Bank, current US dollars[14]

Observing these developments, economic historians have tried to advance explanations and uncover the critical factors for divergence. Unfortunately, there is no simple answer. Disasters such as civil wars and international conflict present countries with periods of low growth and impoverish their population and destroy economic assets. Long periods of stability sometimes do not shore up significant economic performance either. Often, and as noted in the previous chapter, we can observe greater innovation and stronger growth during periods of change that allow new incentives to emerge. Strong economic growth tends to coincide with accelerated development of technologies and innovation.

Ceteris paribus, there are a number of conditions that are likely to have a positive impact on growth, i.e. that allow technology and innovation to maximize their impact. First, access to a large domestic or export market is an advantage for economic experimentation while economies of scale can boost competitiveness and incentivize investing in technology and taking on the risk of innovation. Second, an economic and institutional culture and regime that supports entrepreneurship, experimentation, and risk taking, while accepting the inevitability of entrepreneurial failure, is a positive factor. Third, human and physical capacities to conduct industrial research and development, product development and prototyping and economic and commercial exploration are essential. Finally, financial capacity eager to engage in uncertain and high-risk ventures provides the foundation.

Countries that have a modest or poor growth performance are often found to be lacking several or all of these conditions. Disadvantages are compounded by policy fragmentation. Poor growth can be

[13] Western offshoots comprise Australia, Canada, New Zealand and the United States.

[14] Word Bank, World DataBank, http://databank.worldbank.org

expected when trade policies, industrial policy, environmental standards, education policy, etc., are insufficiently coordinated and do not operate in concert with other STI policies or overall development strategy.

3.2 Policies on technology to innovation policy

Since the turn of the century, policymakers in developing countries increasingly recognize two issues. The first is that all countries need to formulate an STI policy that supports innovation driven development. Innovation is no longer the exclusive domain of developed economies nor is the lack of development finance the singular problem of the developing world. Several developing countries have already achieved significant economic growth through innovation. Others urgently need to develop a more positive policy environment for technology and innovation as pillars of development. While most countries will have some technology-based sectors and industries, many structural and systemic challenges hinder their development, in particular in least developed countries (LDCs). This is often due to the second issue: STI policy has often been poorly linked to national development goals and strategies.

Some progress in economic and social development is possible without innovation if social and economic resources are not fully employed. However, such extensive economic growth will stall when the use or access to one or more critical resources approach full capacity or become limited. Innovation comes to the rescue as it recombines available resources, increases the effectiveness of their use or proposes alternatives, and reestablishes the basis for economic growth. The resulting productivity growth is a direct outcome of product or process innovation. Economic research has traditionally focused on the role of technology in economic growth (Solow, 1956; Lucas, 1988; Romer, 1990) but not on innovation as such. However, understanding technology as only one component of an innovation process, and as described in unit 1, is useful because it guides us towards a broader discussion and a holistic consideration of the relationship between STI and economic development.

Defining science and technology policy by assessing particular needs and individual problems and proposing capacity-building or technical measures is an approach that can bring a certain level of success. In international deliberations, such as the UN MDGs, STI policy has concentrated on issues such as access to essential medicines, mitigating the effects of climate change, internet connectivity and ICTs. However, such reactive and case-by-case methodologies can be insufficiently supportive of the development of technological learning and sustainable innovation capacities. Positive results, however welcome, can cloud the need to develop stronger policy linkages and a more purposeful policy action.

Increasing the acuteness of the problem is the fact that technological catch-up with developed countries may no longer be a valid or sufficient policy target as a number of current technologies lack environmental sustainability. Natural resources are finite and developing countries will need to do better than catch-up. Traditionally, promoting equitable and inclusive economic development was linked to promoting access to the knowledge resources in developed countries. However, the realization that learning and innovation arise from interaction, guides policymakers to think in terms of creating dynamic national systems of innovation, as discussed in unit 1 Introduction. Thus, access to knowledge and technology, and policies on trade, technology transfer, intellectual property rights and STI partnerships[15] will need to be synchronized with a principal innovation strategy clearly linked to national development goals.

3.3 Economics and technology and innovation

[15] UN (2010) cites World Bank research which suggests that STI partnerships have been ad hoc and limited in their capacity to promote systemic improvement as well as being unsustainable, while often operating in isolation from other related concurrent donor funded activities and not always linked to the priority needs of developing countries.

Academic economics is scattered with attempts to give technology – and innovation as its practical embodiment – a meaningful place. Perhaps this is because the idea that increases in productivity account for the bulk of aggregate economic growth is not controversial. This idea had been broadly accepted by historically notable economists such as Smith, Marx, Marshall and Schumpeter (Metcalfe, 2010). More recent empirical research, such as Hulten and Isaksson (2007), who consider innovation to be interchangeable with *total factor productivity*[16], conclude that it is the major contributor to differences in development levels across countries. It should be noted that not all innovation is growth. Certain innovation efforts can yield greater product diversity without much or any growth. The brief discussion that follows describes the development of economic thinking on growth, and technology and innovation, since the middle of the twentieth century.

In the works of Cassel (1924), Domar (1946) and Harrod (1939), economic growth was understood to be a function of the rate of savings. Savings deposits where available for investment which, in turn, caused a growth in the stock of capital. This resulted in higher economic output, but only if and when investments exceeded the depreciation of capital stock. Thus, societies and nations that saved more would have sufficient means to generate a net increase of their capital stock which would result in a growing economy. However, diminishing returns on capital and labor suggest that as economies mature, the rate of economic growth will decelerate and almost stop. Advances in technology, if and when they happened, would be included in new investments replacing depreciated capital stock. Policymakers had as options to increase savings, decrease capital depreciation, and increase the effectiveness of new investments through improvements in technology. However, innovation and technology were determined exogenously – they were not something that could be promoted by active economic policy.

Developing countries where largely seen as being held back by a lack of finance for development. The common sense idea that technology and economic development were closely related did not help economists to incorporate technology into their analysis. Fagerberg (2007) suggests that this is because technology was mainly seen as freely available knowledge that could be used without being depleted. Therefore, because it could benefit the entire world to the same extent, it could not explain differences in development.

Solow (1957) and Swan (1956) suggested that technical progress, in addition to capital and labor, was a critical factor for economic growth. They proposed that economic output is a function of capital and labour, and technical change. Diminishing returns to capital and labor remained, but technical change provided a way out by sustaining growth in productivity and, as a consequence, economic growth and development. Solow explained: "*... I am using the phrase 'technical change' as a short-hand expression for any kind of shift in the production function. Thus slowdowns, speedups, improvements in the education of the labour force, and all sorts of things will appear as 'technical change'*." However, Solow and Swan also suggested that their *technical change* is determined exogenously – it is a given, it is unpredictable and is unexplained. Policymakers are thus guided to consider using savings rates, capital investment, capital depreciation rates, and labor as policy levers, much like in Cassel, Domar and Harrod.

Several directions in economic theory on growth during the second half of the twentieth century have proximate relationships with technology and innovation systems thinking. Rostow (1960), in his *stages of economic growth* model, identified five stages of which the fourth stage, *the drive to maturity* is characterized by, "*... the (economic) capacity to move beyond the original industries which powered its take-off and to absorb and to apply efficiently over a very wide range of its resources – if not the whole range – the most advanced fruits of ... modern technology.*" Kuznets (1971) proposed that economic growth occurs as a result of the interaction between advancing technology and changing institutional and ideological frameworks. Such perspectives may be considered as sources of present-day systems

[16] Total factor productivity is a term used to describe the part of economic growth that cannot be explained only by a simple growth in inputs.

of innovation thinking. Kuznets also explained that technological advance tends to feed back onto itself, thus providing a basis for continuous and sustainable growth. Regarding developing countries, Kuznets suggested that, *"…substantial economic advance … may require modifications in the available stock of material technology, and probably even greater innovations in political and social structure."*

Hirschman's work on economic development is indicative of attempts to find a greater complexity in understanding growth outside of mainstream economic doctrines. Hirschman references historic paths and embraces the notion of political economics, thereby removing economics from its self-made seclusion in a world of models and hard data. In *Exit, Voice and Loyalty* (1970) he argues for the case of active policy, or "Voice", which he contrasts against the short-termism of free markets, or "Exit", i.e. consumers or shareholders "voting" with their purchasing power or investment sentiment. Hirschman proposes that a policy response to a socio-economic problem would necessarily involve a larger group of stakeholders and would trigger communication and learning processes, as opposed to a meager market response. He generalizes his approach to address issues at firm, market and macroeconomic and political levels. His concern with failure is that if it is treated with an "Exit" response, the opportunities for learning and advance are lost. In this sense, Hirschman works towards a systems perspective without explicitly addressing innovation.

Starting in the mid-60s, a diverse group of economists, among which Arrow (1962), Romer (1986), Lucas (1988) and Grossman and Helpman (1992), argued that the actual sources and determinants of growth needed to be explained by the proposed economic theory. It was suggested that these determinants were investment in human capital and in research and development, eventually leading to technological progress. This so-called "endogenous growth" theory or "new growth theory" differed from Solow and Swan as it suggested that the rate of technological progress and innovation, and by consequence economic growth, could be influenced by economic factors and policy. It also suggested that human capital and technological knowledge were different facets of the same thing. The notion of diminishing returns was also questioned. The development of the knowledge economy and accelerated technological advance established the possibility of the existence of increasing returns on investment.

The policy conclusions of endogenous growth theory were different compared to Solow and Swan. Instead of influencing savings rates, policymakers were guided to increase spending on R&D and human capital development as variations in growth rates were more likely due to differences in productivity growth rather than in rates of capital accumulation. Unfortunately, endogenous growth theory better describes growth in developed countries than in developing countries because developing countries generally have modest R&D activities while knowledge is imported and technology is transferred from abroad, rather than developed locally in the form of human capital. Therefore policy in developing countries is destined to address broader determinants of productivity as proposed by innovation economics and systems theory and discussed in unit 1 and 5.

Innovation or evolutionary economics propose an alternative perspective on the issue of growth and technology. Schumpeter (1911, 1942) suggested that institutions, entrepreneurs, and technological change were the key factors of economic growth. What moved an economy forward were *"... new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization."*[17] Much like endogenous growth theory, innovation economics tries to understand how innovation occurs and sees it as a cumulative result of activities of many economic stakeholders – primarily entrepreneurs (Baumol, 2002) – but also institutions and public bodies. Where it differs is that it considers economies to be in a permanent dynamic disequilibrium: this non-state is the generator of development. It also embraces the notion of uncertainty in economic matters, rather than assume narrow definitions of rational behaviors of firms, consumers, government and other

[17] Schumpeter's discussion on creative destruction and innovation is presented in unit 3.

economic agents. Innovation systems thinking readily bridges the fields of microeconomics and macroeconomics and is relatively open to influences from other academic disciplines.

There are a number of key insights that are proposed by innovation economics. First, innovation primarily drives growth, while savings and capital accumulation have a supportive role. Secondly, economic development is essentially a process of restructuring and reallocation of resources, forced by new products and technologies replacing the old i.e., what Schumpeter called *"creative destruction"*. The process of creative destruction is fragile and political short-sightedness may sterilize it by seeking to protect established industries or social contracts (Caballero and Hammour, 2000). Thirdly, innovation efficiency – how capable is a society to develop new products, services and processes – takes precedent over allocative efficiency as a policy target. The effective allocation of resources through competitive markets with minimal government intervention should not be a top policy priority as it does not generate growth, in particular in countries where market failures and institutional inadequacies are commonplace. Fourthly, innovation is an evolutionary process laden with trial and error attempts that lead to frequent dead-ends and rare successes while firms interact and act on inadequate information. Fifthly, in addition to technology and human capital, institutions, entrepreneurial cultures, social norms, regulations, and networks are central to economic development. Finally, the main policy recommendation is to support the development of a national system of innovation.

During the last two decades, the academic consideration of innovation has embraced a number of non-economics influences and fields and has become an increasingly interdisciplinary subject. This has led to the development of national systems of innovation as a policy framework and will be discussed at greater length in unit 5 of this manual.

3.4 Rate of innovation, growth and policy

Two related economic developments are giving concern to economists and policymakers and could suggest that innovation may be slowing down. The first is stagnant or decreasing real income of lower and middle class households in developed economies. This means that any increase in demand that might stimulate growth would come from households taking out new loans thereby increasing private debt levels. Such growth is eventually matched by periods of decline caused by households paying back debt instead of consuming. The second is the financialization of the real economy as profits are increasingly generated in financial markets rather than in goods and services markets (Krippner, 2005; UNCTAD, 2015). This change has several facets. The first is the decrease in output of manufacturing industries relative to a comparable increase in financial services industries. The second is that financial investors, if they are not venture capitalists, habitually pursue financial returns with a limited interest in firms and entrepreneurs competing through technology development and product innovation. Finally, while the financial sector has the experience and tools to deal with risk, applying these to Knightian uncertainty – as encountered in innovation – may not yield meaningful decisions.

In a financialized economy, innovation increasingly comes from competition in stagnant markets usually through efforts at product differentiation that may have little impact on productivity growth. Some data supports such evaluations: the impact of innovation in the last two decades is not comparable to the period 1945-1975 and for all the advance in ICTs, it is difficult to assess if any growth has come from this sector by looking at productivity data (Solow, 1987)[18]. Chart 3 describes productivity trends in several developed economies since 1960.

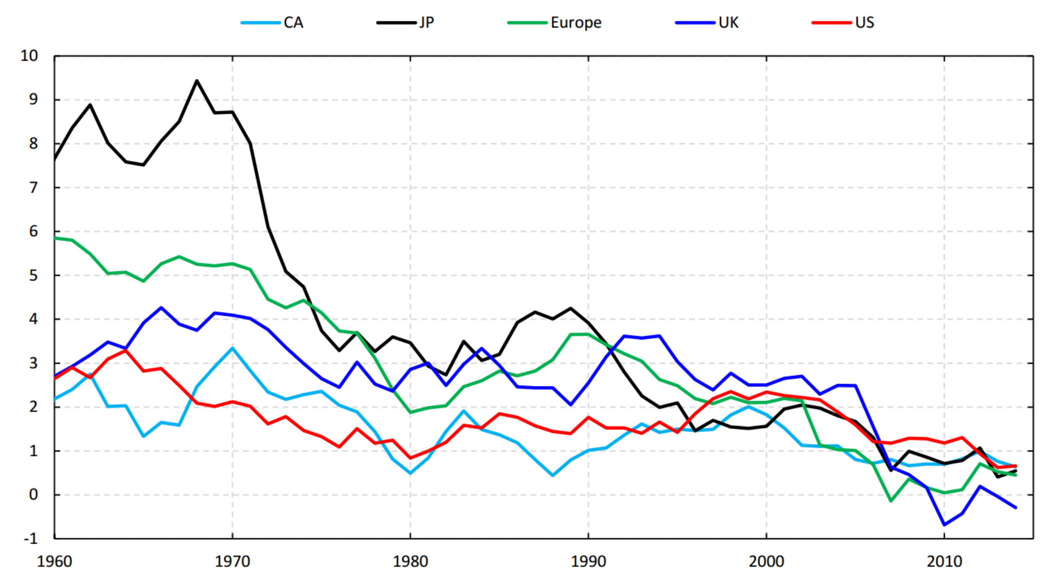
Viewed outside the context of global economic development, this slowing down of productivity growth is sometimes seen as being caused by the slowing down of innovation (The Economist, 2013). Gordon (2012) suggest that, even if innovation continues to fuel growth, major obstacles may be presented by

[18] Solow asserted that, "*You can see the computer age everywhere but in the productivity statistics.*" (Solow, 1987).

the relative decline of the working population, the rise in the price of higher education, an increasing inequality of income distribution, globalization, climate change, and macroeconomic volatility enhanced by cycles of increasing and decreasing private and public debt. On the other hand, Brynjolfsson and McAfee (2012) argue that the current post-great recession jobless recovery is actually a manifestation of massive Great Restructuring in industry, mostly caused by the intensification of digital technologies. While digital technologies can disrupt certain sectors and industries, *"…they require parallel innovation in business models, organizational processes structures, institutions, and skills."* and in the medium- to long-term will be a net contributor to growth.

Hirschi (2013) questions whether innovations in developed countries actually offset the magnitude of their Schumpeterian creative destruction with their positive effects on growth. The increasingly weaker impact of invention on innovation and by consequence on growth in developed economies may be a cause for reflection in the developing world. UNCTAD (2013a) concludes that many countries are adjusting to this reality and growth in the developing world is being increasingly driven by domestic demand, as import demand in developed economies has remained weak in recent years. As well, the share of South-South trade in total world exports has doubled over the last 20 years, to over 25 per cent (UNCTAD, 2013b).

Chart 3: Labour productivity growth*



Source: Conference Board Total Economy Database, IMF World Economic Outlook.[19]
* % 5 per year centered moving average; Europe indicates average rate in France, Germany and Italy.

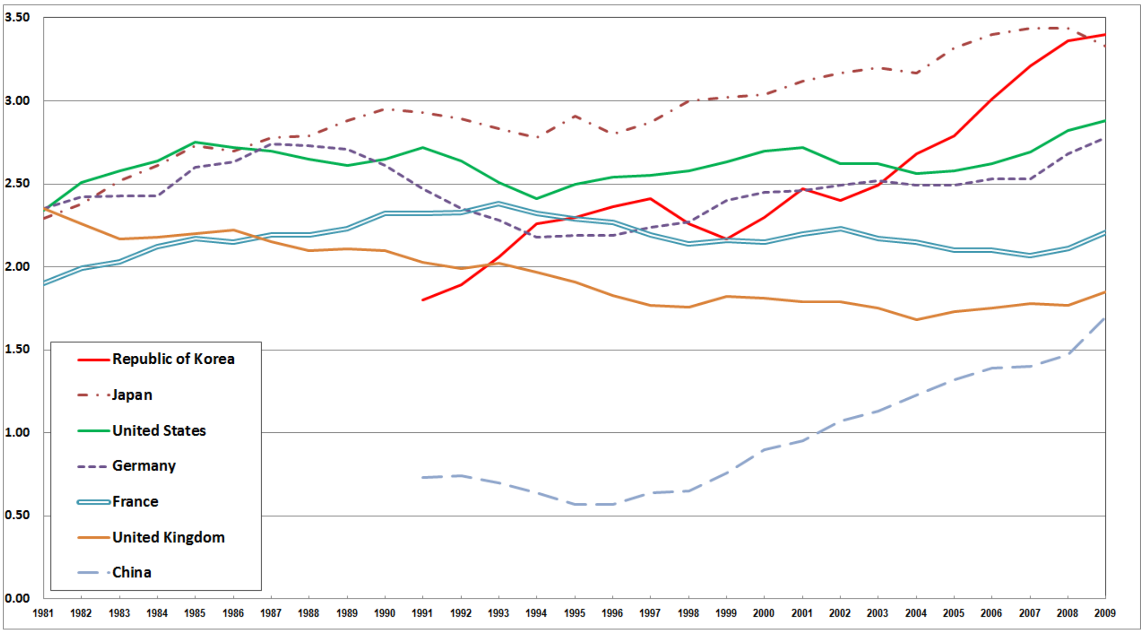
Under conditions of slowing productivity growth, attempts to improve innovation through better policy can lead governments to assess developments before 1975, when productivity and economic growth were stronger. The obvious question would be what positive features did the science, R&D and innovation process have back then that may be diminished or missing today. However, conclusions may be misleading in particular for policymakers from developing countries and should be read with caution as macroeconomic and structural conditions and growth perspectives are often significantly different. In addition, the misguided presumption of a linear innovation model works its way back into policy thinking. As a result, two key concerns show up for debate. One is how to support basic science and scientific research. The idea is that effective science produces quality inventions which then stand a better chance of commercial success, i.e. becoming innovations. The second concern is how to use competition and markets in improving the effectiveness of science, i.e. its transformation into

[19] https://www.fulcrumasset.com/assets/Document/FulcrumResearchFollowingtheTrend.pdf

innovation. The implied question is whether science is more or less effective when it is not accountable, neither to government policy objectives nor to markets.

Hirschi (2013) cites Merton (1942), Mees (1950) and Kelly (1950) and suggests that the era of accelerated innovation that ended in mid-70s genuinely saw science as requiring the largest amount of freedom to act in order to be effective. This necessarily meant a freedom from feedback from government policy and markets. Kelly specifically advanced that while scientists working in academia were already fairly free, those in industry needed to be provided with similar freedoms as their university counterparts. The difference between academic science and research conducted in industry was that in industry there was a greater need for interaction and communication among disciplines to increase the chances of producing viable commercial products. In order for creativity to flourish, interactions needed to be spontaneous and informal and therefore the ergonomics of research and laboratory environments needed to accommodate and encourage them.

Chart 4: Gross R&D as a per cent of GDP, 1981-2009



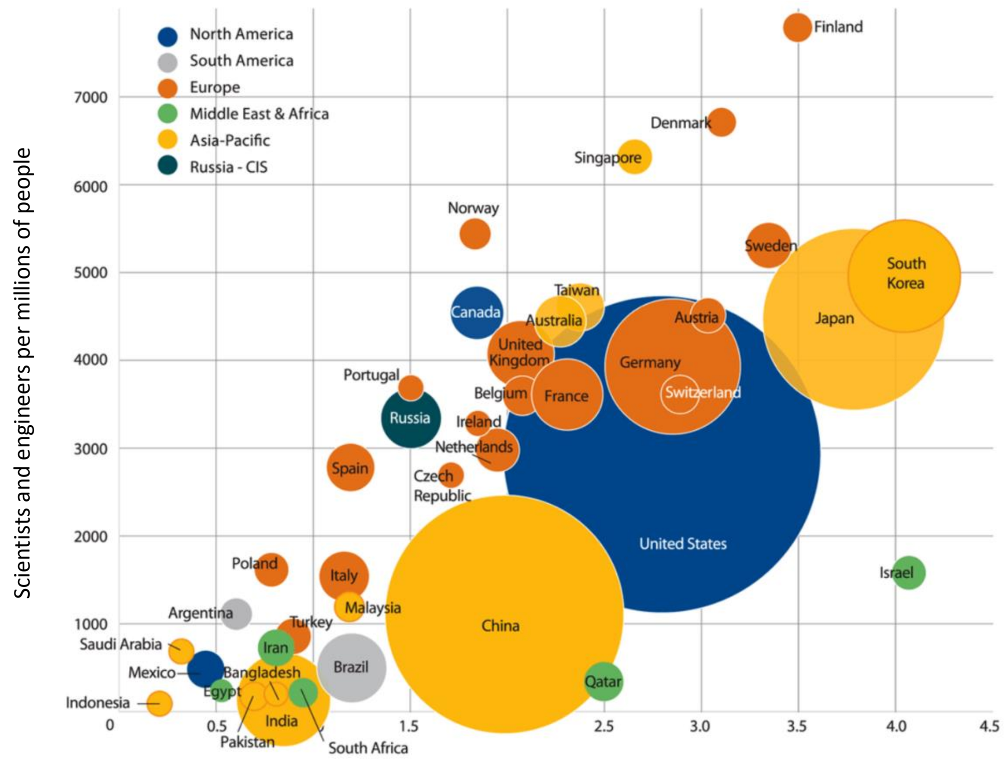
Source: NSF (2012). Science and Engineering Indicators 2012[20]

In the United States, such policies where short-lived as many industrial monopolies – which were the cradles of applied science – weakened, vanished or where dismantled by regulators. In a compensating development, public funding for scientific research – mostly now conducted in academic environments – grew and has now reached a plateau in developed economies. Ideological perspectives shifted as well in the 1980s and the nature and extent of government involvement in science was questioned. Instead of reducing public funding for science, market oriented R&D has become the guiding principle in developed economies, research is increasingly conducted in joint public and private partnerships, while the linear understanding of innovation has been replaced with an innovation systems approach in public discourse, if not fully in practice. Charts 4 and 5 illustrate trends and developments in R&D.
From a policy perspective there is a problem. While linear innovation thinking was never considered as a policy model to be implemented, it re-enters policy through efforts at assessing innovation performance by focusing on inputs such as money spent on R&D, number of graduates per discipline or number and types of patents filed which are a rough equivalent of inventions, but not innovation. The implied "linear" logic of such measurement is that science produces invention and invention causes innovation which drives economic growth. A supplementary assumption is that all this occurs in a competitive market economy. Measuring how science and R&D "generate" inventions in terms of

[20] http://www.nsf.gov/statistics/seind12/c4/c4s8.htm#s6

research outcomes, such as publications in academic journals or patents filed, is much easier. Likewise, assuming that certain conditions benefit innovation and measuring those, is doable as well. However, measuring innovation itself – how many inventions actually became profitable innovations and what proportion actually resulted in improve productivity and economic growth – is a difficult exercise.

Chart 5: R&D in 2016*



Source: 2017 Global R & D Funding Forecast[21]

* Size of circle represents the relative amount of annual R&D spending by country.

Regardless of the policy experimentation in the previous three decades, the results are not impressive. This poses important dilemmas for developing country policymakers: if a non-linear innovation systems approach has produced ambiguous results in the developed world, why would it be useful in a development context? The answer may lie in understanding that the macroeconomic trend of financialization and the resulting volatility of economic cycles, characterized by asset market bubbles and significant swings in leveraging and deleveraging, has completely swamped policies that aim at growth and development.

While keeping an eye on policy experimentation and processes in developed economies, policymakers in developing countries should consider several circumstances that are specific to development. The first is that human capital is underutilized and many countries witness important emigration and brain drain. A second is that, both extensive growth and productivity growth – in other words, bridging both the financing and the technology and innovation gap – require functional institutions and frameworks. Development policy will require a mix of both, tailored to specific national circumstance. Finally and as already mentioned several times, there is a heightened need for policy coordination among the various public resources in order to perform on a coherent national development strategy. A national system of innovation approach is useful not only because it is non-linear in its understanding of innovation, but because it recognizes that the complexity of the development challenge can only be met by supporting cooperation, linkages and interaction of all stakeholders, including those outside the immediate scope of technology policy.

[21] http://tinyurl.com/globalrnd2011

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Selected reading materials

1. Science, technology and innovation for sustainable development in the global partnership for development beyond 2015. UN System Task Team (2011).

2. Innovation for Development. OECD (May 2012).

3. Why Promote Innovation? The Key to Economic, Social, and Environmental Progress. World Bank (2010) in "Innovation Policy: A Guide for Developing Countries"

4. The Organization of Innovation - The History of an Obsession, (Hirschi, 2013).

Unit 4. Creative destruction, disruption and role of change

The goal of unit 3 is to bring together three themes that are common in policy discussions on innovation – creative destruction, disruptive innovation and the role of change – and relate these to critical assessments of the effect of innovation on growth.

Innovation theory proposes a number of themes that influence policy development and dialogue. One distinctive theme is Schumpeter's concept of creative destruction. A more recent deliberation, and following on Schumpeter, tackles the issue of disruptive innovation. A third theme is the relationship between innovation and societal change. These are themes that sometimes appear in discussions on the nature of innovation, it's role in economic development and how a systems approach can propose certain advantages for policy, or not..

4.1 Schumpeter and the process of creative destruction

In chapter VII of his 1942 treatise *Capitalism, Socialism and Democracy*, Schumpeter proposes that the process of creative destruction needs to be understood in the context of a capitalist economy with imperfect competition, where greater or lesser monopolies are commonplace. Framing the discussion, Schumpeter suggests that it is difficult to establish that imperfect competition necessarily holds back output and growth as there is no comparable period in economic history that had perfect competition and that could serve as a control group when analyzing data. To the contrary, large firms can make disproportionate contributions to economic growth as their capacity to face uncertainty, and finance and produce innovation, outrivals smaller players.

Capitalism is an evolutionary process. Economic change is its essence and it is never stationary. Schumpeter postulates that, *"…the fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates."* Other contributors to the economic dynamism of capitalism, such as changes in the social and natural environment, demographics or even short-term monetary economic policy, merely embellish its fundamental evolutionary nature. Growth is a process of industrial mutation where new products and productive technologies relentlessly destroy the old. This is the process of creative destruction and it is the essence of capitalism.

Embracing creative destruction has two corollaries. The first is that policymakers need to adopt a dynamic perspective and discount static snapshots of economic performance as incomplete. Strong long-run performance may depend on short-term underperformance to achieve maximum output. The second is that because creative destruction, and more generally the functioning of an economy, is an organic process, an analysis of a firm or industry in isolation does not generate much or any replicable policy advice or insight. Financial data from a firm, when considered under the assumption that a firm's objective is profit maximization, will shed some light on how the firm manages in its current environment, but will not explain how it creates or destroys it.

Creative destruction renders traditional understandings of competition unworkable. Competition through product differentiation and marketing dilute the importance of price. A much greater change occurs when competition is understood as the appearance of a new commodity, a new technology, the new resource or type of organization. Such competition – materially or even as a threat of the appearance of such competition – affects more than profit margins: it impacts the economic foundations of competing firms. Schumpeter concludes that the competition that matters for growth and which describes the essence of capitalism is the one that is a game changer, not transient disruptions due to new but minor entrants in established or stagnant markets.

Creative destruction is not a neutral concept: it creates clear winners and losers. Financially strong firms can increase market share and put competition out of business through price dumping, reinforcing their dominant position but without bringing any innovation to the market. Creative destruction can improve or worsen income distribution when firms enter or leave certain localities or countries. Building or reconfiguring global value chains may produce positive effects on income in countries where transnational or multinational company establish production and transfer technology, but can have devastating effects on regions where and when production closes. Compared to the late 1930s when Schumpeter developed his views on innovation and creative destruction, the post-millennium international economy is profoundly globalized in terms of trade, technology, FDI and capital flows. It is also more dynamic and volatile and this should guide policymakers towards a deeper consideration of Schumpeter's insights.

4.2 Disruptive innovation

Christensen (1997), much like Schumpeter, proposes that a *disruptive innovation* is one that helps create a new market and value network, by disrupting an existing market and value network. It is disruptive because it improves a product or service in ways that incumbent firms do not expect. Sometimes the term *disruptive technology* is used interchangeably. However, technology becomes disruptive only when imbedded in a business as an innovation. A broader understanding of disruptive innovation sees it as having a profound impact on many economic and commercial activities, community and individual welfare, and everyday life. Examples of such disruptive innovations in the past are, to name a few, rail transport, electrical power, ICTs, vaccines and antibiotics or artificial fertilizer. However, it is difficult to predict if any one innovation can have such an historic impact and it is even less clear what enabling mechanisms can be provided or whether those policy mechanisms themselves can survive the disruption. Therefore, this discussion will only look at firm and market level disruptive innovation.

Unlike Schumpeter, Christensen suggests that companies with dominant market positions are not good at disruptive innovation. Even though they have resources to spare, they have a strong preference for incremental innovation. Start-ups and small companies may therefore acquire a competitive advantage by choosing to be disruptive. They are able to do so because, in the main, disruptive innovation does not attempt to deliver incrementally improved products in mature markets. Rather, they disrupt by redefining the use value of a product or a service and aiming at simplicity, convenience and cost, instead of enhancing technical sophistication or performance. However, once the disruptive product has established sales and market share, the technological improvement cycle begins and eventually leads to improved technical sophistication, often surpassing the products or services it displaced. Such disruptive innovation presents a critical challenge to incumbent businesses. Often, there is neither a perceived incentive nor a plan to compete with a disruption coming from the low-end of the market and many firms will react to avoid head-on competition by moving their products up-market in price and technical sophistication.

As the process works its way through a sector and industry, disrupters become the new incumbents and dominant firms fail or restructure themselves beyond recognition while new disruptive forces arrive. The process is recognizable, but it is not ubiquitous; there are entire sectors and industries that thrive on incremental technological progress and innovation. Sometimes, established firms will try disruptive innovation. Such a decision may encounter a poverty of incentives within the firm and may clash with an established institutional culture. It would therefore be prudent to consider setting up an autonomous business entity for such ventures. Understanding firm-level issues related to disruptive innovation is important if policymakers intend to develop innovation financing mechanisms such as joint public-private venture capital funds.

Disruptive innovation is fundamentally a microeconomic and firm level concept and macroeconomic effects can be discerned only at the medium- to long-term, in particular from a growth and development perspective. An obvious example of disruption becoming mature was the development of Japanese engineering and technology companies during the '60s and '70s. The disruptive force of the likes of Sony, Nippon Steel, Toyota, Honda or Canon during this period morphed into incremental innovation as Japan's economy stagnated from the beginning of the '90s onward. In the '00s they have themselves been disrupted by competitors from the Republic of Korea and China. Clearly there are other factors and circumstance at play, but it is undeniable that these and other companies were important contributors to Japans rapid post war development.

Policymakers and financiers involved in developing support and funding mechanisms, including venture capital, to spur innovation in developing countries may wish to select funding candidates with an ability to disrupt. Established and incumbent businesses must recognize the potentially disruptive nature of innovation and, if they feel able to innovate, should be prepared to severely transform if not cannibalize exiting business ahead of the competition. Christensen suggests that there are several criteria that can be used to determine whether an innovation proposition is sufficiently disruptive.

The first is assessing whether there is a potentially large market that is untapped because consumers cannot pay or do not have sufficient user skills (i.e. the current technology is inconvenient). Targeting less-skilled or less affluent people with products that were previously only accessible to the skilled and affluent is a genuinely disruptive proposition. However, it is dependent on customers being happy to purchase and own a lesser but still good-enough product.

A second criterion is whether a technological process and business model can be developed to deliver such a product while still earning a profit. The last criterion and question is: does the innovation disrupt all incumbent firms or only some? If the innovation is not broadly disruptive, it stands little chance to succeed. However, policymakers may need to accept that not all innovative ideas can be shaped into disruptive strategies as the necessary preconditions may be scarce. Policy efforts at innovation will need to engage as well with established and large firms as these may have advantages in incremental innovation.

4.3 Change and innovation in practice

As discussed in unit 1, adopting an NSI framework for STI policy will require dropping the assumption that innovation is a direct result of investment in science and R&D and understanding that it is only one of several important inputs in the innovation process. Still, policymakers need to answer the question, "When does innovation occur?" in order to formulate effective and relevant policy. This requires improving the understanding of the practice of innovation, in firms and by entrepreneurs, and among key STI stakeholders. In the words of Drucker (2002) "*What all successful entrepreneurs … have in common is a commitment to the systematic practice of innovation. … The heart of (entrepreneurship) is innovation: the effort to create purposeful, focused change in an enterprise's economic or social potential.*"

Innovation often happens when economic and social circumstances change and firms and entrepreneurs see incentives to respond. Examples are changing demographics and markets, changes due to new knowledge or information channels and technologies, natural or man-made threats (e.g. climate change, war, disease, etc.), changes in regulations (e.g. new technical standards and requirements, international harmonization of regulations) or the appearance of social or economic contradictions (e.g. increasing lifespan coupled with increased number of old-age illnesses), just to name a few. Inversely, economic and social stability can be upset by creative destruction disruptive innovation processes. Unit 5 discusses this issue in greater detail.

The response to such changes can be targeted innovation that is focused on a specific opportunity – market demand or public need – and using a specific invention. However, many accidental matches of solutions to problems have been known to occur as well. Regardless of the role of chance, innovation is a largely empirical endeavor and a quest to find out what works and how consumers will respond. Trial and error is an important process not only in defining how knowledge and technology can be used to innovate, but also in the course of learning, improving absorptive capacities and internalizing tacit and experiential knowledge by firms and entrepreneurs.

In practice, many attempts to innovate will fail and will provide valuable feedback on how to proceed, perhaps guiding the search for alternative solutions or problems. Failure itself can lead to accidental and essential sources of innovation opportunity. In this regard, it is important that policymakers resist the temptation of falling back on linear innovation thinking that firmly sequences science and R&D to product development. Considering that a failure to validate STI funding with successful results – i.e. innovative products or services – must be an entirely negative outcome can draw attention away from unanticipated opportunities.

Changes in industry and market structures can create important innovation opportunities in particular for startups and SMEs. In contrast, it is not uncommon for established or large companies to act defensively and (re)focus on core business lines when threatened with new knowledge or technologies. In doing so, they risk neglecting new and fast growing markets. Innovation opportunities may not correspond to business models and operational practice of mature firms, while they may have technological competencies and access to finance.

From an innovation policy perspective, the question of focusing primarily on major national or regional firms should be examined critically as the dynamism of startups and small and medium-sized enterprises (SMEs) can compensate for their disadvantages of minor size and experience. Entrepreneurs and firms that innovate will necessarily challenge the economic status quo and this, in turn, will reinforce the need for a functioning national competition policy and authority to protect them from unfair competition from and incumbent producers and service providers with significant vested interests.

The temptation to involve only a few industry-leading firms in national innovation strategies may be easier work for policymakers but may also risk producing inadequate results. However, completely ignoring large and established companies would also be a mistake as they can be partners and investors in smaller, more dynamic firms, and key actors in scaling up production and commercialization. An innovation ecosystem requires both, as innovation through acquisition – large established firms buying startups for their innovation potential – becomes a commonplace and global practice.

A change of perception among entrepreneurs about innovation opportunities can be a reaction to a change in factual economic circumstance but also to the policy environment. Hence the importance that policymakers make particular efforts to clearly and unambiguously communicate their innovation policies and actions. Highlighting what measures of support will be available to STI stakeholders that are keen to increase collaboration is critically important in setting expectations.

New knowledge can enhance innovation opportunities. Its creation and diffusion can be significantly influenced by policies in a number of areas such as education, vocational training, scientific research, or management and technical regulations and standards. However, policymakers in developing countries may appreciate that lead times for innovation based on new knowledge can run into years and decades and therefore it may be prudent to bias policy support toward identification, adaptation, diffusion and commercialization of exiting knowledge and technologies. This does not mean abandoning scientific research altogether. To the contrary, the support for an appropriate level and direction of academic and scientific research activities serves to create human capacity required to engage in commercially oriented innovation.

In addition, not all knowledge is technological, and innovation outcomes will therefore depend equally on non-technological process innovation. Illustrations for this can be the local introduction or development of innovations in finance, management, logistics or marketing. Drukker (2002) gives as an example the success of commercial aircraft producers in that it was as much dependent on researching user needs in terms of route and payload development, as well as innovations in finance such as operational and finance leasing.

Entrepreneurs and innovators will look at many sources of opportunity and insight, including receiving feedback from consumers as well as suppliers and sub-contractors. Many are certainly aware that effective innovation can – and often does – start on a small scale, while ideas that promise to dramatically change a market or industry are often loaded with hypothetical assumptions or rely on conditions and circumstance that are difficult to foresee or control. Of course, every now and then an innovation will end up becoming a big business, market or industrial sector, but policymakers may be wise to focus on supporting an NSI and enabling innovation in general, rather than picking hypothetical winners.

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Selected reading materials

1. Chapter VII: The Process of Creative Destruction, Joseph Schumpeter (1943) in *Capitalism, Socialism & Democracy*.

2. Disruptive Innovation, Clayton Christensen (2000)

3. The Discipline of Innovation, Peter Drucker (2002) in *Harvard Business Review*

Unit 5. Public policy and STI

The goal of unit 5 is to explore the issue of the role of public policy in influencing the direction of STI practice and funding particular activities. While conclusions may not be one-sided, the discussion suggests that questions of sustainability and policy prioritization are addressed.

5.1 Public support and funding of STI

Public policy can affect innovation and economic growth through diverse channels. Macroeconomic stability, competitive markets, competent regulation, and a culture of entrepreneurship all support innovation. Direct support of STI in the form of public funding for scientific research is a phenomenon of the post-World War II period (Gomory, 1992). Such policies were based on the assumption that scientific knowledge was a transformative factor with direct and positive consequences on economic development. Progress in atomic physics, solid state electronics, ICTs, molecular biology and life science, had easily demonstrable impact on everyday life. The rationale for public funding was based on a generalized appreciation of success achieved so far.

Several decades later, perspectives started to change. The innovation experiences of countries like Japan, Finland or The Republic of Korea demonstrated that there could be room for public policy beyond funding scientific research in universities. Policy could support applied research as well as an environment amenable to the commercialization of science and technology, i.e. innovation. To replicate their experience policymakers in developing countries would need to clearly articulate goals for basic science, applied research, R&D and innovation in terms of process, indicators and commitment of funds and human resources.

Initially, the main policy argument for the public funding of science was that competitive markets failed to perform in delivering the scientific and R&D results needed for innovation. This was because the full economic value of a new scientific insight was unlikely to be fully appropriated by its discoverer when knowledge can be diffused at ever decreasing costs especially with ubiquitous and improving ICTs. Thus, the value of science for society is often higher than the private value for the scientist and this suboptimal incentive requires correction through public funding (Bernanke, 2011). Strategies to improve funding presume that there is sufficient human capacity to engage research, that there are available and qualified scientists, engineers, and technicians. Strengthening IPRs has also been proposed as a solution to improving incentives. However, such measures have a downside and may impede innovation in practice. As discussed in unit 1, in recent decades, the realization that innovation is the outcome of interactions among a variety of stakeholders has led policymakers to consider funding and supporting system-wide interactions and establishing national systems of innovation to improve policy coordination.

There have been arguments against Government funding of scientific research and assistance for commercialization of inventions claiming that science is not as public a good as it is assumed (Kealy, 1996). Kealy explains that understanding scientific research and R&D sufficiently to appropriate the results of others has a definite cost. The cost is expressed in the education and competency of the experts and the infrastructure required to conduct such an exercise. Acquiring information by researching and reading through registered patents, participating in professional and academic conferences and programmes, and being informed and knowledgeable at an expert level are costs that should not be ignored. Kealy suggests that public funding of STI crowds out private funding from foundations for basic science and firms for innovation. On the other hand, public funding can benefit very large firms who have special relationships with national governments and may lobby to have their research needs assigned to academia as national priorities. However this is an anti-competitive policy putting at disadvantage SMEs and discouraging innovation among them. Finally, public funding creates a risk that academics lose their intellectual and scientific independence while pursuing funding from

Governments that may have vested and short-term interests specific to their ideologies, narrow electoral mandates, or vested interests of strong lobbies.

5.2 Supporting innovation: questions and dilemmas

Governments can support innovation through their STI policy platforms. Many governments will provide indirect support for STI. The most basic level of indirect support is funding vocational training and academic institutions, their students or both. These institutions will produce the nation's scientists, engineers, soft technology experts and entrepreneurs, as well as technicians and artisans. Other types of indirect support are investments in infrastructure, in particular in ICTs and broadband internet connectivity, and investments in STI and industrial parks. At the other end of the scale we find direct STI support where governments fund specific scientific and R&D projects and institutions and establish funding mechanism for innovative startups. In between there are many possibilities for government to play an active role by creating an environment that stimulates innovation. In spite of this complexity, much of the academic and policy debate on public support for STI gets simplified as the following question: to what extent should government finance specific science and R&D projects.

Deciding to publicly fund STI activities, or not, is a political process. Priorities will need to be established and the resources that are allocated to science and R&D projects will not be available for other purposes. Good policy practice would necessarily mean aligning the funding of STI with the overall national development strategy. The key concern is whether policymakers are well placed to evaluate market demand and commercial potential as well as the national potential to innovate. Dilemmas may appear about going for innovations that may be proximate to existing sectors and industries or supporting the development of entirely new products and markets. Regulations may need to be changed to unleash creative potential, meet requirements in new markets and assure consumers. A well founded understanding and recognition of the disruptive, destructive and change-related nature of innovation, as discussed in unit 4, can serve as a beacon for setting the policy course.

Funding agencies may encounter three potential pitfalls.

First, wishing to avoid of public scrutiny or criticism, *they may become overly cautious and choose to focus on a limited number of low-risk projects or to direct funding to established institutions* rather than seeking out candidates with the highest innovation potential.

Secondly, *funding agencies may try to avoid redundancy* even when research and innovation practice shows that pursuing multiple approaches or mandating several teams to a research task can increase the chance of innovation through cooperation or constructive competition. Redundancy is often mistakenly perceived as cost-ineffective or even wasteful. Understanding innovation as an evolutionary process moves funding agencies to identify research dead ends, as well as paths with potential, at the earliest possible stages.

Finally, funding agencies may *choose to prioritize short-term projects hoping these can show results, appease legislators and extend mandates in the current electoral and political cycle*. Public funding for STI will be more effective if it is thought of as a long-run investment. Time lags from science to R&D to innovation and commercialization, and onto development impact can be lengthy. Public support will achieve better results if funding is stable and has set its objectives in the long-term and has clearly communicated such a policy to the public at large.

The problem becomes more acute when national leadership choses to pick industries or particular firms – sometimes referred to as *picking winners* – and support large projects as a matter of development strategy or industrial policy. Deliberations may question whether there is a true need for a strategy beyond public support for some science activities at a few universities. Policy discussion may express some level of confidence, or lack off, about the capacity of consumer demand and markets to provide sufficient signals to labor, entrepreneurs and financiers, to effectively allocate resources including into STI activities. Concerns may be voiced about STI budgets going out of control, failing on promises or crowding out private investment. Finally, views on the links between innovation and competitiveness may be expressed and comments about the similarity between STI and industrial policy may be voiced. This can bring ideological differences and recent historical experience on the capacity of the state and the quality of governance into the discussion.

If policy discussions, as illustrated above, are to have a coherent and actionable conclusion, it is advisable to adopt an NSI framework for STI policy. The primary purpose of a NSI is to assist in determining the nature of public support of STI issues based on a thoughtful consideration of local conditions. It does so understanding that innovation is not a linear process[22] and that it is the result of interaction between governments, academia and business acting on market signals and diverse public policy. A national innovation policy may encounter any number of issues, some of which are other active polices that were developed and implemented before a NSI framework was considered. Examples of these may be official national research priorities, scientific research directly linked to innovation in state-owned firms and industry, IPR policy with strong focus on patents and royalties as policy results even though these are only inputs to the innovation process, or public competitions or awards for applied research and invention that can be misinterpreted to be innovation. In addition, policy support for STI can be expressed through procurement policies, policies on human resources mobility, technology extension services, metrology, and standards development. Without an NSI bringing together stakeholders, interests and concerns, policymakers may quickly move from a complex challenge to a chaos of fragmented polices.

5.3 Academia and STI policy

Untouched by STI policy, most academic institutions will teach and conduct research corresponding to the demand at enrolment for postgraduate and doctoral programmes and in the areas of global interest for the particular disciplines of its departments and faculties. STI policy should aim to affect the balance of graduates and competencies to better match development ambitions and employment opportunities. Often, adjustments may need to be made to reduce the relative production of certain competencies for which job prospects are meager. However, there is no blanket prescription as innovation requires scientific, technology and non-technological skills and knowledge to enable economic discovery and innovation. Competencies in fields such as law, business, economics, logistics, communications, management and marketing are important parts of the national human capital.

STI policy may also influence or guide scientific and applied research by awarding funding to specific projects and departments or funding facilities and infrastructure that aim to enhance collaboration such as innovation and STI parks or business incubators. At the same time universities need to attract students by offering an appropriate mix of educational and research opportunities and professional perspectives. The academic prestige of a university will depend on many factors including its reputation for scientific research as well as linkages with industry. The mobility of human resources between academia and firms is a good indicator of policy performance. STI policy my need to reach down to levels of public primary and secondary education. It is there where the capacity for critical and creative thinking is seeded. Finally, STI policy has a crucial role to play by working to align education policy with development policy and national ambitions. Using a national system of innovation framework, STI policy can contribute to coordinating diverse actions and reducing policy fragmentation.

5.4 STI policy and sustainable development

[22] See unit 1.2 for a longer discussion.

The current path of global economic growth and development is not sustainable. Neither market incentives nor regulation at national level, nor international deliberations and agreements have encouraged innovation on the scale required to elude some of the most distressing consequences of the current environmental trajectory. The task is daunting: reduce climate-change risks, improve energy security, improve access to food, energy and water for the poor, improve environmental quality, public health, act diligently as a steward of biodiversity, all while responding to aspirations of people in developing countries to live like their counterparts in developed nations. Responding to this challenge, in 2015 United Nations member States adopted a new sustainable development agenda specified as 17 Sustainable Development Goals.[23] In no uncertain terms, Sustainable Development Goal #9 declares that, *"Technological progress is the foundation of efforts to achieve environmental objectives, such as increased resource and energy-efficiency. Without technology and innovation, industrialization will not happen, and without industrialization, development will not happen."* Sustainable Development Goal #17 stresses the need for action in partnerships between governments, the private sector and civil society – the stakeholders of a national system of innovation. Goal #17 explains that urgent action is needed to mobilize, private resources towards long-term investments addressing issues such as sustainable energy, infrastructure and transport, as well as ICTs. Policymakers will need to set a clear direction and review policy frameworks, regulations and incentive structures.

International efforts to promote North-South and South-South collaboration must include action to facilitate technology transfer. Innovation is the key to mitigating the impact and adapting to the consequences of climate change. This is a burden that falls disproportionately on developing countries. While rapid development and deployment of green technologies are critical to sustainable development, markets are failing to generate results. As well, there are diverse views about what public policy on technology transfer should address, internationally and at the national level as well. The mode of transfer of particular technologies that can enable green and sustainable development has been at the heart of many debates at the international level, often accompanied by reflections of the purposefulness and fairness of intellectual property regimes.

From a practical point of view, there is little if any difference in the STI policy toolkit and complexity when addressing sustainable development issues as opposed to general growth and development concerns. However, the level of determination to implement will need to radically change. For example, the increased importance of inclusiveness in order to achieve social sustainability needs to permeate STI policy. Positive incentives, direct and indirect, regulations and public awareness campaigns will require funding commitments. Regulations and efficiency standards aimed at reinforcing sustainable consumer and production practice are not only a matter of legislating, but also of implementing the law. Market-based measures such as a carbon tax or emissions-trading programmes can be considered. Subsidies are a double-edged sword: they can improve the adoption of new technologies but may become a barrier to disruptive innovation. If this is the case, removing subsidies may be a key policy measure. For example, several oil-rich countries have bellow or at-cost fuel prices at retail as a part of social policy (UNCTAD, 2014b). At the same time this is a huge disincentive for the development of alternative energy sources and improving energy efficiency. However, increasing prices to discourage oil consumption and promote innovation can impoverish lower-income households and may conflict with development policy aimed at poverty alleviation.

Given the potential disruptive nature of technologies and innovation that can be used to achieve sustainable development, established firms and industries can be expected to occasionally suspect or resist public policy. This problem can be addressed by decreasing policy uncertainty to allow both innovative and incumbent firms to plan for competition or partnerships. An important source of policy uncertainty is diverging short- and long-term viewpoints on the purpose of policy and the nature of outcomes. A common example is policy on IPR whereby a Government will commit to international

[23] See http://www.un.org/sustainabledevelopment/

standards and become a party to agreements even though domestic industry may have modest capabilities to create intellectual property while strict enforcement discourages innovation through copying and local adaptation for local use. Poor linkages between short- and long-term objectives also generate policy uncertainty. An example of this may be the funding of early stage innovation – through research grants or supporting public or joint public-private venture capital funds and incubator and innovation centers at public universities but without developing comparable support for commercialization and scaling up of production. Finally, engaging in effective, time-bound consultative mechanisms in policy formulation and predictable implementation timelines will also reduce uncertainty.

The challenges of innovating for sustainability present promising opportunities to strengthen policies and practices in South–South cooperation on STI. UNCTAD (2012) proposes a number of principles that could inform policies in this regard. Developing countries should also increase efforts to develop clear and focused national strategies that take advantage of technologies under public licences, in the public domain and using local knowledge and resources.

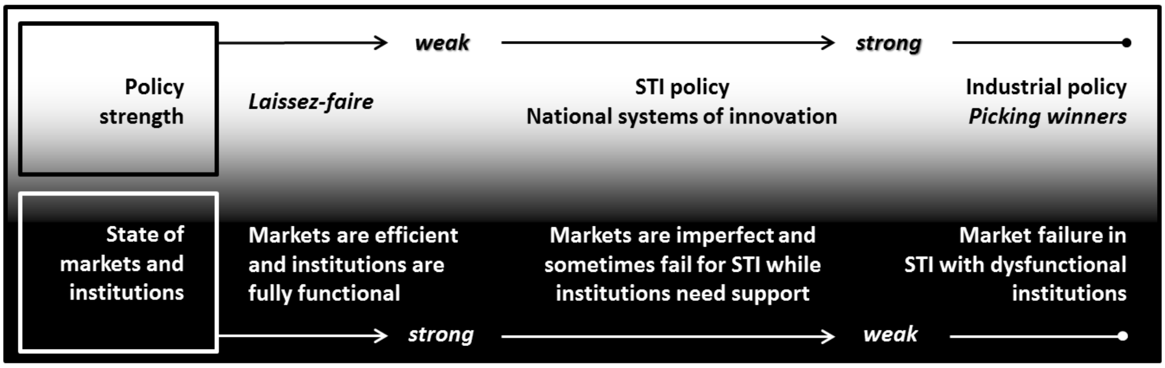
5.5 STI policy and prioritization

Developing countries often face several prioritization challenges. One such challenge is assessing the level of technology where public support and funding achieves the greatest impact. Often the policy dilemma is phrased as: are public funds worth spending on support for high-tech innovation? The decision is often considered in relation to the fairly common problems of unemployment or low wage or value-added jobs while reckoning that the outcomes of STI policies can be ambiguous in terms of their impact on salaries and employment. There are two possible and complementary strategies to deal with this issue. The first is for policy to focus on supporting the environment for innovation rather than actual technologies. Firms and entrepreneurs will then choose to innovate and absorb appropriate technologies based on reading their markets. The second is to establish a coordinating mechanism between policymakers and representatives of funding agencies, education and industry, in an effort to synchronize institutional actions to better match STI and development strategy.

Another possible policy challenge is whether or not innovation policy should involve *picking winners* among firms and industries. This question needs to be considered as choosing one point or position on the policy spectrum of government intervention in market and systemic outcomes. Chart 6 graphically describes a framework for considering the strength of policy. On one end there is *laissez faire*. The middle is populated by policies supporting framework conditions and funding R&D and applied research which private interests deem too risky – typically cases of market failure of underinvestment in STI. On the opposite end lie industrial policies. Mapping such policies against real world situations suggests that *laissez faire* is an acceptable policy response when markets are efficient and effective and systemic circumstances – governance and inter-institutional relationships – are exemplary. Supporting framework conditions and funding STI plots against conditions of lesser or greater market failure and institutional capabilities. Picking winners and industrial policy requires serious consideration when a country faces both market and systemic failures.

Critics of industrial policy argued that it introduces distortions in the market. Decreasing a market's effectiveness in allocating money and resources creates problems such as goods shortages, overvalued exchange rates, credit restrictions and price controls. Supporting projects such as import substitution, non-viable domestic and public firms in priority sectors, infant industries or state monopolies are often highlighted as poor practice. However, such discussions and criticisms – much like the linear model of innovation – are often merely academic. In practice, many developed economies successfully engage in some kind of industrial policy (Stiglitz, 2013). Developing countries may have the most to benefit from applying some level of industrial policy appropriate to their strategic development and STI policy aspirations. It is a legitimate policy because development involves structural transformation and diversification, processes which build rather than exploit existing comparative advantages and which implicate public institutions and involve governance structures beyond the policy goals of ensuring property rights, contract enforcement, and macroeconomic stability (Rodrik, 2004).

Chart 6: Policy strength, markets and institutions



The third challenge is deciding on the structure of desired term of impact, as a choice of balance between short- and long-term policies. UNCTAD (2014) has suggested that both need to be pursued simultaneously; it is only the impact of some policies that may be long-term or delayed. Short-term impact policies are sometimes called harvesting *low-hanging fruit* and several are suggested as follows. Access to affordable and high quality ICTs and connectivity is critical, in particular when innovation is to occur in SMEs and startups. Conducting an institutional audit can discover and eliminate pricing, regulatory, legal and behavioral obstacles of a formal and informal nature. Leveraging public procurement and infrastructure projects and improving access for SMEs to public procurement contracts can stimulate innovation. Increasing support to innovation centers and incubators in academic and research institutes can have short-term impact on human capacity development while innovation outcomes themselves should be considered a medium-term target. Adjusting the output of tertiary education in consultation with employers, be they government or industry, may have modest short-term impact which should increase towards the medium-term as policies are fine-tuned based on continuous feedback and evolving linkages. Whatever gains are made in the near-term, it is paramount to clearly communicate these to the widest public.

Finally, the development of policymaking and implementation capacity for STI in government institutions is by itself a serious challenge. A profound understanding of STI issues among key decision-makers needs to be developed. In addition, a sufficient understanding needs to be introduced among STI stakeholders before STI policy can be undertaken with a minimum prospect of success. To achieve this, knowledge flows must be energized and formal knowledge transfers should be complemented by tacit knowledge flows and experiential learning through collaboration between firms, academia and government.

The key long-term policy in terms of impact is the development of an exemplary national system of innovation. Its success should be measured by the increase of the absorptive capacity of national firms and industries and their innovation outputs. Specific actions with long-term perspective can include building a country's knowledge base, strengthening human resources through education at all stages and stimulating youth creativity and entrepreneurship. Strengthening R&D and innovation will require new funding schemes and technical and commercial support, in particular assistance in technology identification and economic experimentation.

Critical mind-set changes may relate to changing attitudes to increase horizontal information flows inside and among firms and institutions, and better understand the nature of risk and uncertainty in innovation. This will require well thought-out and persistent public relations efforts supported by *leadership by example* by policymakers. Other long-term action can relate to providing support for sustainable or green innovation and fostering related international and regional STI cooperation. Developing an evidence-based system for evaluating outcomes of STI policy using data on national science and technology assets, R&D statistics, innovation performance indicators and regular innovation surveys are long-term activities that require immediate engagement. Finally, the social impact of innovation, in terms of unemployment or the differential impact on the livelihoods and empowerment of men and women, will require close monitoring and assessment against concurrent innovation policies or disruptions from new innovation activities or technologies.

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3. The role of government and the contribution of science and technology, InterAcademy Council (2007) in *Lighting the Way: Toward a Sustainable Energy Future*.

4. Promoting Research and Development: The Government's Role, in *Issues in Science and Technology* 27, no. 4.

5. The Economics of Science: Interview with Terence Kealey, JR Minkel (2003) in *Scientific American*.

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Unit 6. National systems of innovation

The goal of unit 5 is to broaden the discussion on national systems of innovation. It discusses key challenges and opportunities for policymakers embracing an NSI approach and thus prepares participants for the exercise in Exercise 9.

6.1 Role of innovation systems concept in policy

This discussion on *national systems of innovation* (NSI) picks up after unit 2 and its presentation of technology and innovation and their relation to development economics and macroeconomics. Unit 4 discussed that economic growth and development are increasingly based on the capabilities of firms and entrepreneurs, and the capacity of an economy, to identify and use knowledge and technologies in a progressively more productive and commercially viable way. In other words, economic development depends on the ability to innovate.[24]

This leads us to the obvious question: how can public policy facilitate innovation? The answer is closely linked to how policymakers view and understand social and economic processes. Often, they will select a convenient set of observable facts – often referred to as *innovation indicators* – and will then infer relationships between them. This process will create a model of the national socio-economic environment. Conventional economics has a strong preference for factors-indicators that have good data, often produced by national statistical services. It eschews those that are difficult to measure or whose definitions or data sets are less precise. Factors such as institutional relationships and knowledge transfers are therefore evaded even though they are critical for understanding innovation processes and creating supportive policies.

NSI theory and policy serves to add some needed complexity. Its objective is to better understand what causes the often significant differences between countries in terms of their capacity to innovate and, by consequence, to develop. To answer this question, Ludvall (1992) proposed exploring the "elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge". In other words we need to develop an understanding of the intensity and quality of interactions among institutions such as firms, academic establishments, and government bodies. As a consequence, policy research established two lines of enquiry (Godin, 2007). The first, led to descriptive research on national institutions, including institutional rules and behaviours, and the organization and functioning of national innovation systems. The second line of enquiry was concerned with how knowledge is created and transferred and gave rise to the concept of the *knowledge economy*. It focused on the capability of an innovation system "to ensure timely access by innovators to the relevant stocks of knowledge" (David and Foray, 1995). Both of these views are components of NSI theory and policy.

6.2 Development of NSI theory and policy

Innovation systems theory and policy has multiple sources going back to economists such as Friedrich List, Thorstein Veblen and Joseph Schumpeter. List (1837) argued for active policy explaining that *"… every responsible government should strive to remove those obstacles that hinder the progress of civilization and should stimulate the growth of those economic forces that a nation carries in its bosom.*" List (1841) also proposed that national strategic interests and development aspirations needed to be the focus of practical economic policy. This meant that "… *those nations which feel themselves to be capable, owing to their moral, intellectual, social, and political circumstances, of developing a*

[24] Clearly, there are a large number of circumstances that affect development and that fall outside the scope of this discussion, such as financial and natural resource endowments, size of markets and potential for developing scale economies, or historic, geographical or climatic circumstances and conditions.

manufacturing power of their own must adopt the system of protection as the most effectual means for this purpose."

Veblen (1898) birthed the school of *evolutionary economics* by questioning the premise that economic systems tend to equilibrium and that economics can be conducted as a science which resembles the physical sciences and by using analogous mathematical tools. Veblen suggested that, instead of seeking equilibrium, economies evolve and can be better described through a dynamic theory of change and development. Evolutionary economics studies innovation as an endogenous phenomenon – it occurs as a result of the interaction of elements inside a system – in an economy and analyzes how innovation emerges, how it spreads across the economy and how, once it is widely adopted, how it creates conditions for continued innovation. Veblen (1915) referred to Germany's experience of industrialization to propose that technological catch-up, as a result of active economic policy, was possible. Veblen explains that Germany's mastery of "*… industrial arts that so has led to the rehabilitation of a dynastic State in Germany on a scale exceeding what had been practicable in earlier times, – this technological advance was not made in Germany but was borrowed … almost wholly, from England.*"

Schumpeter's role in understanding innovation as an evolutionary process of creative destruction is discussed in unit 4.

Another important source of NSI theory was the dialogue at the OECD and its predecessor, the OEEC, on the economic role of science. Charged with implementing the Marshall Plan in post-Second World War Europe, the OEEC/OECD was concerned with the effective use of allocated resources, and in particular with how science could accelerate economic growth. These concerns led to numerous expert consultations, with supporting research being produced between the late 1950s and mid-1980s, predating current NSI theory. At the time, Europe was seen as lagging behind the United States in translating science into growth. The problem was diagnosed as insufficient relevance of scientific research for economic policy objectives while fragmented research activities lacked a common goal. The solution was seen in improving the linkages between academia, industry and government in order to increase the relevance of scientific research to its economic environment (Godin, 2007), (OECD, 1972).

Another predecessor or source of NSI theory was the study of catch-up of Japan, the Republic of Korea and Taiwan, Province of China and other South-east Asian economies. The analysis often focused on the development of technological absorptive capacities and capabilities in firms (Fagerberg and Godinho, 2005). A key success factor was the ability to finance this development in order to scale up production from an organizational, technological and marketing perspective. As a result, the main elements of an innovation process were linked into an implied innovation system. The overwhelming strength of public policy decisions and the determination in implementation that led to economic success merits emphasis (UNCTAD, 2014a and 2014c). In practice, to actually develop capacities and capabilities to innovate means exploring policies that easily fall into the domain of industrial policy and picking winners in sectors and industries. This policy fact is often downplayed as it is seen to be contrary to the *laissez-faire* economic doctrine promoted by many international agencies that extend funding and technical assistance to developing countries.[25]

During the 1990s, the theoretical discussion on the role of policy in knowledge and technology transfer between firms and academia birthed the concept of the national system of innovation. With its roots in evolutionary economics, and following on developments in new growth theory (see unit 2 of this

[25] An excellent example is the classic World Bank (1993) study, The East Asian Miracle: Economic Growth and Public Policy, which explained that, "…*widely shared, market-friendly policies are the foundation of East Asia's economic success. Industrial policy narrowly defined – that is, attempts to achieve more rapid productivity growth by altering industrial structure – was generally not successful*." See: http://tinyurl.com/worlbank-miracle.

module), NSI theory suggests that innovation is a systemic and endogenous process: it occurs through the interaction of knowledge and institutions in an economic, social and political environment. Academic literature provides many different definitions of innovation systems (see a sample in box 2).

From the 1990s onwards, NSI theory has expanded the scope of discussions by introducing new institutions and relationships, such as collaborative networks, STI clusters, civil society and social innovation, or user involvement through open innovation. It also moved away from considering government as the chief policy owner and initiator and considers the role of public policy to be one of facilitation that supports the various conditions necessary for innovation. NSI theory has, as well, changed the focus of STI policy from academia and research institutions to firms and entrepreneurs.

Box 2: Innovation systems definitions

"... The network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies." (Freeman, 1987)

"... The elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge ... and are either located within or rooted inside the borders of a nation State." (Lundvall, 1992)

"... The set of institutions whose interactions determine the innovative performance of national firms." (Nelson and Rosenberg, 1993)

"... The national system of innovation is constituted by the institutions and economic structures affecting the rate and direction of technological change in the society" (Edquist and Lundvall, 1993)

"... The system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology" (Niosi et al., 1993)

"... The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country" (Patel and Pavitt, 1994)

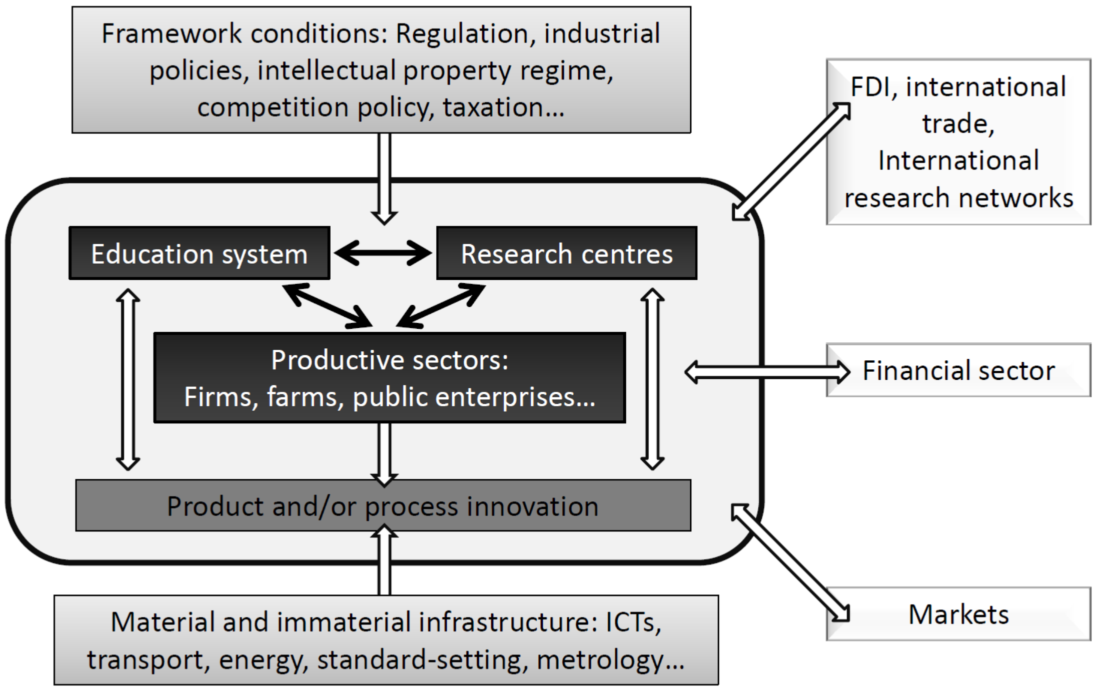
"…System of interconnected institutions to create, store and transfer the knowledge and skills and artefacts which define new technologies" (Metcalfe, 1995)

Source: UNCTAD, 2011

Chart 7 describes several fundamental elements and interactions in a typical NSI. Even this simplified presentation of an NSI suggests that STI policy is complex and demanding in its design, implementation and monitoring. Such a policy is not only concerned with the strengthening of the "supply side" of knowledge and technology, but needs also to consider the management of the "demand side" – the use that firms and public sector entities make of knowledge and technology in the production of goods and services. To accomplish this, STI policy framed by an NSI is profoundly concerned with the interactions between these two sides and with the incentives presented by the policy environment and social and economic realities.

NSI frameworks have been adopted, in various degrees of formality, in most developed countries. However, the adoption of an NSI approach in developing countries is a more recent phenomenon. Many of them are making first steps while others are experiencing slow starts with policies that struggle to go beyond declarations and into practical implementation. The reasons will be as varied as economic and social circumstance. However, just as innovation occurs in an environment, an NSI has its own national environment which enables its success. Several elements stand out in particular. These include good governance, institutional capabilities and sufficient macroeconomic stability. Knowledge flows as well as trade and investment links need to be developed. Another key feature of a pro-innovation environment is an entrepreneurial culture of risk-taking and the acceptance of innovation and commercial failure as necessary events in innovation processes. Finally, an effective NSI can only exist where and when the national economic development strategy has evolved and recognizes the role of science, technology and innovation.

Chart 7: Elements of a national system of innovation



Source: UNCTAD, 2011

6.3 NSI governance in practice

Many countries have some kind of NSI coordinating mechanism that aims to engage STI stakeholders and enhance their interactions. It works towards enhancing the competencies of STI institutions and motivates the upgrade of absorptive capacities in firms and industries. There is no generally accepted best practice on how to develop formal NSI coordination, mostly because the experiences and structures that have developed are the result of an evolution of policy practice. A plethora of insight can be had by consulting innovation policy reviews conducted by the international organizations such as the OECD and, of course, UNCTAD.[26] The effectiveness of strong coordination at the top level of government can be illustrated several through NSI success stories, such as those of Finland or Singapore.

Finland

The most commonly used example of a functional NSI is that of Finland – a small country with average natural resource endowments. Finland's key coordinating mechanism has been the Research and Innovation Council (called the ST Policy Council at its creation in 1990). This Council is chaired by the Prime Minister and involves all key ministers (including the Finance Minister) and heads of concerned agencies including the Academy of Sciences and the Innovation Promotion Agency, as well as top representatives of business, civil society organizations and trade unions. The council discusses the implementation of strategic decisions, including budgets, sector reforms and new programmes.

Another important measure taken by Finland in the 1970s was the creation of an R&D funding and support body (SITRA) operating directly under the Finnish Parliament. This body organizes seminars and events for political leaders, business managers, and workforce representatives to keep them informed and involved in the STI policy issues of the day. SITRA has often been convoked to review policies and STI developments. Still operating today, SITRA has been instrumental in facilitating reform processes in

[26] See https://www.oecd.org/sti/inno/oecdreviewsofinnovationpolicy.htm, and http://unctad.org/en/pages/publications/Science,-Technology-and-Innovation-Policy-Reviews-(STIP-Reviews).aspx

Finland and adaptation to global opportunities and external shocks and pressures. The Finnish Funding Agency for Innovation (TEKES) is a publicly funded vehicle for financing research, development and innovation. Its activities extend to research communities, industry and service sectors. Tekes promotes a broad understanding of innovation and funds service-related, design, business, and social innovations as well as technological innovation. It regularly cooperates with on public research projects at universities and research institutes. Funding projects are selected based on their potential for creating long-term economic and social. In addition, the Finnish Industry Investment company and the Finnvera credit agency are both state-owned investment firms active in funding innovative startups and active stakeholders in the Finnish NSI.

Singapore

Singapore started developing its NSI in 1989 by establishing a Committee of Ministers of State. The Commission produced the "The Next Lap" development strategy which singled out R&D and high-technology sectiors as priorities for the next two decades. This was followed up with the first in a series of five-year National (Science) Technology Plans (NSTP) and a National Science and Technology Board (NSTB) was established to implement NSTPs. The NSTB was restructured in 2001 and renamed the Agency for Science, Technology and Research (A*STAR) while technology and innovation entrepreneurship policy was shifted to the Economic Development Board (EDB). During the '00s, there were efforts to establish a strong science and research capacity. Since 2010, policy emphasis has shifted towards technology commercialization, public-private R&D partnerships and the establishment of technology transfer offices and enterprise incubators. (OECD, 2013)

Singapore does not have a separate ministry for STI but its Ministry of Trade and Industry is responsible for coordinating STI and supervises the work of EDB and A*STAR. STI governance is handled by the Research, Innovation and Enterprise Council (RIEC) which is chaired by the Prime Minister. The Prime Minister appoints Council members to two-year terms, selecting among Cabinet Ministers and distinguished local and foreign members from the business, science and technology communities. Established in 2006, the RIEC decides on the national R&D strategy and STI funding priorities by reviewing and approving the national Strategic Research Programme which governs the work of the top-level National Research Foundation - a department within the Prime Minister's Office.

6.4 NSI challenges

Changing mindsets

The development of an NSI involves the coevolution of capabilities among various categories of socioeconomic players as well as of the environment in which they evolve and interact. Many countries have difficulties in kick starting the required virtuous dynamics that are intrinsic to such co-evolutionary processes. Political cycles are also usually shorter than the time scale needed for the incremental development of an NSI. This poses serious challenges as the establishment of broad social contract and national development strategies, of which an NSI is a part, will need to subordinate electoral and political cycles and endure whatever inescapable social turbulence may come its way. Countries that can overcome such hurdles still need to reckon with natural and historic endowments and legacies. They also need to manage in an international policy environment that disfavors interventionist or activist policies and adjust to function within a decreasing policy space. Finally, developing countries face an accelerating pace of technological change that increases requirements for investment in human capital in order to catch-up (Fagerberg and Godinho, 2005).

Following decades of perceiving a free-market economy as an economic ideal, developing country policymakers, and in particular their economic advisors educated in the corresponding economic theories, may find it demanding to revisit their prior knowledge and prejudgments, and reconsider what an NSI perspective proposes. The general problem, as Hirschman noted and as discussed in unit 2, is that free markets, including those for labor, underperform on encouraging processes of interactive learning and transfers of tacit knowledge. Not to say that such processes are absent, but without long-term non-market relationships based on common history, culture, industrial tradition, loyalty and trust, they will be weaker, *ceteris paribus*. A perfectly competitive market economy inhabited by short-term oriented individuals who are risk averse and respond by adapting rather than innovating will result in stagnant economies. In practice, it is difficult to find many such economies among developed countries. A healthy majority has explored and many have assimilated NSI perceptions and developed more or less formal support mechanisms for their NSI and coordinate their explicit and implicit STI policies.

Evidence-based policy

A major challenge for NSI policy is measuring the innovation performance of an economy in a way that would provide for the assessment of public STI policy and allow for adjustments and corrections. Successful policy will therefore depend on developing a set of measurable indicators. These will typically address the creation of knowledge, development of human resources, funding, technology transfer and diffusion, international collaboration and market outcomes.

Indicators may be referenced against the level of overall economic development expressed as GDP. One frequently quoted indicator is R&D spending either per capita or as a per cent of GDP. It is a good example that highlights three specific problems which policymakers need to overcome by consistently being mindful of the context and limitations of measurement. The first is that R&D spending per capita or as a per cent of GDP is an input into one part of the innovation process; it is not an outcome and policy success should not be assumed if the numbers are growing. The second is that R&D has different intensities in different sectors and industries. Assessments citing average R&D in money terms may not reflect the true nature or scope of innovative activities. Numbers will have meaning only when read in context with the sectorial structure of national economy – the balance of services, agriculture, industry, or mining and energy sectors, the proportion of large and small firms, and its relations with trading partners (Nahan and Quirk, 2006). The third is that the direction of causality may be misread – in this case that an increase in R&D spending will generate innovation and spur growth. Unfortunately, the complexity of most national economies may not corroborate such a simplification. Large or growing public R&D spending can be a result of growth and development instead of vice versa. Observing the US economy, Sveikauskas (2007) concludes that university and government research often generate very low economic returns and mostly contribute indirectly to economic growth, if and when private firms chose to commercialize research outcomes.

A similar measurement problem can be observed for education (Pritchett, 2001). Policy success may be misconstrued if it is assessed by counting the number of graduates at various levels and types of education and vocational training, and analyzing test scores. The human capital that education creates is only an input into economic and innovation processes. Whether it will contribute to growth and development depends on a number of circumstances. Of major influence are the implementation of a well-articulated national development strategy supported by auxiliary policies for development finance and STI, the fit of human capital to the current and future needs of the economy, and an objective and verifiable assessment of educational quality in terms of both inputs and outcomes. Lacking these, investment in education may generate paltry returns and can slow down economic growth. A typical manifestation of such poor policy coordination is the immigration of educated and skilled youth.

Data that is regularly used in policy work often deals with the size and quality of inputs into innovation processes. Typical examples would be graduates of the secondary and tertiary education systems, patents filed, number of researchers employed, per cent of GDP spent on R&D activities or academic papers published by nationals. Examples of such attempts to measure innovation performance are the

Cornell University-INSEAD-WIPO Global Innovation Index[27], the Bloomberg Innovation Index[28], the Innovation in American Regions Index[29], or the EU Innovation Union Scoreboard[30]. Among often cited reference for innovation measurement are the OECD *Frascati Manual* and *Oslo Manual* which guide the collection of national data on R&D and, more generally, surveys on science and technology surveys by the UNESCO Institute for Statistics (UIS), and the collection and use of firm-level data on innovation activities.[31] The *Frascati Manual*, by its very nature, focuses on inputs. The *Oslo Manual* focuses on innovation in firms and does not examine macro changes such as the emergence of new markets, the development new intermediate goods or services, or changes in structures and operations in industrial sectors.

The idea that data on innovation outcomes, in addition to inputs, can enhance policy development and management is generally acknowledged. For example, the EU Innovation Scoreboard includes assessments of innovation outputs by measuring employment in “fast growing firms in innovative sectors” or “sales of new to market or new to firm innovations”. As well, taking cues from firm-level use of metrics can be useful. This may require developing an understanding of the strength of innovation outcomes and how they are related to the entrepreneurial risk taking and activities with uncertain outcomes. Table 2 presents one possible perspective on this issue.

Table 2: Innovation risk and uncertainty levels, actions and outcomes[32]

Risk and uncertainty level		**➡**	**High risk and uncertainty**
Entrepreneurial action		**• Investment in emerging knowledge and technologies**	
		Innovation outcome	*▫ Develop new products and markets*
		Innovation outcome	*▫ Develop new business models/platforms*
Risk and uncertainty level		**➡**	**Medium risk and uncertainty**
Entrepreneurial action		**• Investment in current technologies and knowledge**	
		Innovation outcome	*▫ Differentiate a product or service*
		Innovation outcome	*▫ Enter in existing industries or markets*
Risk and uncertainty level		**➡**	**Low risk and uncertainty**
Entrepreneurial action		**• Investment in common, established technologies**	
Entrepreneurial action		**• Investment in performance systems that incentivize identification and implementation of appropriate knowledge and technologies**	
		Innovation outcome	*▫ Product line extensions and enhancements*
		Innovation outcome	*▫ Business process improvement*

Measuring will also require a dynamic approach whereby a change in ratio between related indicators describes whether innovation is accelerating or decelerating, for example:

- Change in ratio of sales from new products and services compared to existing products and services;
- Change in ratio of profit from new products and services compared to existing products and services;
- Change in the proportion of customers for new products and services compared to the number of customers for old products;
- Change in new technological capabilities compared to technology transfer flows.

[27] https://www.globalinnovationindex.org/
[28] http://www.bloomberg.com/graphics/2015-innovative-countries/
[29] http://www.statsamerica.org/innovation/
[30] http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards/index_en.htm
[31] See http://tinyurl.com/oecd-frascati and http://tinyurl.com/oecd-oslo.
[32] http://www.corporateinnovationonline.com

Several additional facets of measurement can be considered. One is the sustainability of an innovation, both in terms of the length of the product cycle and ability to pass from disruptive to incremental innovation, as well as from an environmental perspective. Another indicator is a change in the proportion of returning clients or client loyalty. On the macro scale, such indicators may be of crucial importance for countries with large tourism or services sectors. Finally, the growth of a market or market share for new products and services is a fundamental innovation indicator.

6.5 NSI opportunities

Making STI policy decisions using an NSI and knowledge economy framework provides several positive opportunities and advantages:

- An NSI perspective can guide policymakers to a deeper consideration of the relationships between STI and society;
- It discourages linear innovation thinking;[33]
- An NSI approach promotes the recognition of the economic importance of knowledge, knowledge flows and knowledge institutions;
- It introduces the transfer of tacit knowledge, as a goal, into policy alongside codified knowledge and general learning through formal education;
- An NSI framework is by definition a multi-stakeholder approach and thus creates opportunities for developing consensus and mobilizing diverse national actors towards development objectives;
- It can increase policy space by introducing policy goals aimed at assisting firms to improve their absorptive capacities for knowledge and technology and facilitating the performance of the network of institutions and linkages that constitute the NSI;
- It can encourage the consideration of economic diversification and competitiveness, and reignites the discussion of new approaches to industrial policy, thereby moving policymaking above mere monetary, trade and finance considerations;
- An NSI perspective offers a more realistic depiction of development processes because it views innovation as inextricably linked to economic and social development realities and guides policymakers to identify leverage points or weak links amenable to policy;
- It allows for learning from the experience of other national systems of innovation.

NSI theory brings into STI policy a notion of historical and national development trajectories, and recognizes that firms, academia and public institutions, operate as STI stakeholders in an economic as well as in a social, political and cultural environment. It suggests that physical proximity and geographic location matter. Interactions and knowledge flows among STI stakeholders are heavily influenced by proximity even if ICTs and broadband access can increasingly compensate for physical remoteness. More broadly, an NSI perspective proposes that stakeholders exist and pursue their interests in a cognitive environment that defines the nature and modes of learning and formal and tacit knowledge flows, and knowledge acquisition and diffusion. In this sense, NSI theory is open to including what may be considered, strictly speaking, non-economic actors and elements into STI policy.

Developing STI policy based on NSI perspectives requires acquiring qualitative knowledge about the local or national innovation environment, in addition to statistically amenable and structured

[33] See unit 1 for a broader discussion on linear innovation models.

information. Behind hard economic data and statistics there is always a narrative that describes how the current situation came to be and the nature of perceptions that various stakeholders have of each other and how they see and understand themselves. For example and in a given country, an important question can be: what is the nature of the relationship between its Ministry of Trade and its Chamber of Commerce and how has their relationship evolved over the years? Do they have a common policy ground, joint activities or participation in policy development or implementation? How do they perceive each other's work and contributions to society? Is non-hierarchical, informal and horizontal communication commonplace and, if not, how did the current situation come to be?

An NSI perspective will highlight the importance of innovation as a source of dynamic competitiveness, while moving away from a strict consideration of comparative advantages and resource allocation efficiencies as the pillars of development policy. It also relegates the question of international technology transfer and IPR to their proper positions as two of many policy considerations and tools. NSI policy can help to refocus policy on the development of technological capabilities and absorptive capacities which are the foundation for identifying, acquiring – including through transfer from abroad and using IPR instruments – adapting and commercializing-innovating knowledge and technologies.

Macroeconomic issues enter NSI theory through examining the linkages between a firm and its microeconomic environment and the macroeconomic world. As discussed in unit 3, a volatile and unstable macroeconomic environment is a source of uncertainty and mostly works against policies designed to spur innovation. Understanding international and national macroeconomic dynamics and ensuing changes is important because they may present opportunities as well as restrictions for domestic innovation policy and innovation processes.

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Selected reading materials

1. National innovation systems, capabilities and economic development. Jan Fagerberg and Martin Srholec (2007). Centre for Technology, Innovation and Culture, University of Oslo, TIK Working Paper on Innovation Studies 20071024.

2. National innovation system: The System approach in Historical Perspective. Benoit Godin (2007).

3. National Innovation Systems Overview and Country Cases. Stephen Feinson (2003).

Exercise 1. Invention and innovation

The objective of exercise 1 is to allow participants to explore their shared understanding of innovation which will be revisited at the end of unit 1. This should allow participants to draw conclusions and establish an understanding about innovation that will facilitate their participation in the rest of the course.

Participants are each asked to suggest five innovations of the greatest importance. These are collected and attached or noted on a whiteboard or flip chart and then hidden from view. At the end of unit 1 presentations and discussions, participants are asked to revise their suggestions by re-categorizing them to be either inventions or innovations.

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Selected viewing material

1. Euractiv: What is Innovation? http://www.youtube.com/watch?v=2NK0WR2GtFs$
2. Jonathon West, Creative Innovation 2010 https://www.youtube.com/watch?v=XEjc44QXdcI

Exercise 2. The innovator and entrepreneur

The goal of exercise 2 is to establish a link between the conceptual and policy discussion in unit 1 and a case example about innovative entrepreneurs and their firms.

The exercise *The innovator and entrepreneur* is an individual exercise. Participants are invited to choose one of the selected reading materials, consult the text in detail and try to develop short answers to as many as possible of the questions listed below.

- Why and how did the entrepreneur become an innovator?
- What particular skills and competencies did the entrepreneur possess?
- What new skills and competencies did the entrepreneur have to acquire?
- What were the fundamental motivations to become an innovative entrepreneur?
- What were the main financial incentives and disincentives?
- What favorable conditions did the entrepreneur encounter?
- What unfavorable conditions did the entrepreneur encounter?
- What was the source of funding?
- What was the source of knowledge?
- Were there any identifiable knowledge and technology transfer flows and processes?
- What was the role of chance or good fortune in their success and when was it encountered?
- Who were the main counterparts and innovation and business partners? How did the entrepreneur discover and engage these partnerships?

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Selected reading materials

1. The miracle of Älmhult, Oliver Burkeman, The Guardian, Thursday 17 June 2004.
2. A Bad Skier's Revenge, Stuart Leuthner, Invention & Technology Magazine, Winter 2004.

Exercise 3. Creative destruction - creative disruption

The goal of exercise 3 is to establish a link between the theoretical concepts in unit three and real-world experience.

The exercise *Creative destruction - creative disruption* is an individual exercise. Participants are invited to reflect on their national experience and choose two examples – one that describes the process of creative destruction and one that illustrates the occurrence of a creative disruption.

Participants will be invited to present their rationale for each example during the training.

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Selected reading materials

1. Chapter VII: The Process of Creative Destruction, Joseph Schumpeter (1943) in *Capitalism, Socialism & Democracy*.

2. Disruptive Innovation, Clayton Christensen (2000)

Exercise 4. Markets vs Policy: Should governments finance STI?

The goal of exercise 4 is to engage participants to represent positions that they may or may not necessarily support, and exercise judgment based on the merits of the presentation and argument.

This exercise is conducted as a competitive debate. The subject of the debate is: *Should government finance STI?*

Participants are divided into three teams:

- The ***For*** team, which argues that government should finance STI activities from public resources;
- The ***Against*** team, which argues that government should not use public funds to finance STI activities; and
- The ***Jury*** team, which asks questions of both teams and at the end of the debate, in a closed session, elaborates its decision on which team won the debate and presents this decision to the *For* team and the *Against* team in a public session.

The debate is competitive and the *Jury* team will judge the winner on the content, style and strategy of its arguments.

The framework for the debate is as follows.

1. At the end of the delivery of unit 4, participants are divided into the three teams: *For*, *Against* and *Jury*. Each team will designate its primary and secondary spokesperson.
2. Participants are instructed to fully consult the relevant unit 4 text in this manual and to consult the selected reading materials with emphasis on Bernanke (2011) and Kealey/Minkel (2003). The debate should be conducted in session on the following day or, if this is not possible, after a two-hour mid-day break.
3. The *For* and *Against* teams must each prepare a five minute statement for which the written text target is about 750 words. The statements must establish and argue the *For* and the *Against* position. The *Jury* team will prepare five questions for each team of which at least three must be identical.
4. The *For* team opens the debate with its opening statement uninterrupted and is immediately followed by the *Against* team presenting its opening statement uninterrupted.
5. Following the opening statements, a five minute pause for reflection and preparation of counter-arguments is established. After this 5 minute pause, the *For* team will have no more than 5 minutes to address the *Against* team's arguments and this will be followed by the *Against* team taking no more than 5 minutes to address the *For* team's arguments.
6. The *Jury* team will ask their pre-prepared questions to the *For* and *Against* teams, one at a time, by question and by team; e.g. question one will be asked and responses from *For* team and *Against* team will be heard before moving on to question two, etc.
7. After questioning is finished, *Against* team and *For* team will be given five minutes to reflect on the discussions and present closing statements with *Against* team going first. The closing statement may be prepared in advance but their success will be judged on, among other things, how much of the discussion has been incorporated to their respective closing arguments.

The *Jury* team will then enter into a private session of no more than 20 minutes after which it will present its judgment statement that will be no longer than five minutes (750 words). The success of the *Jury* team will be established by its ability to consider the arguments and responses during the debate while avoiding completely its own prejudgments on the question of whether government should fund STI activities.

Exercise 5. Innovation policy in Norland: a case study

The goal of this exercise is to insert participants as NSI expert consultants into a case situation that requires critical use of insights presented in this module.

At the beginning of the period under examination (2012) the Ministry of Science and Technological Development decided that its major policy goal was to increase the number of students finishing tertiary education in science, engineering and medicine and to increase the number of scientists and researchers so as to exploit science and technology for national development.

During the period 2012-2015 Norland saw the following developments.

- The Ministry of Science and Technological Development was mandated to develop and promote scientific and research activities by executive order of the President.
- A competitiveness and innovation project (ICIP) for small- and medium- sized enterprises was established by the Ministry of Economy and Regional Development.
- A Ministry of Economy and Regional Development funded Research and Development Institute (NoReDI) was established to promote research and development addressing the needs of :
  - Government agencies, regional and local administrations,
  - Private sector firms,
  - Government companies (energy, transport infrastructure, telecommunications).

  NoReDI was designated to manage three regional science and technology parks of which one has been operational since 2013 while two are in planning phase.
- A Norland Innovation Fund was established reporting to the Ministry of Science and Technological Development. The beneficiaries are researchers in academia. Funding $ 30,000.- is awarded on a competitive basis to five proposals each year. Only 3 proposals qualified each in the 2012 and 2013, one in 2014 and none in 2015.
- The National Council for Higher Education held two events during the period:
  - The Conference of Norland Research Universities, and
  - The Conference of Norland Universities and Professional Studies,

  and reported outcomes directly to the Chief of the cabinet of the President of Norland.
- A National Team of Higher Education Reform Experts was established reporting directly to the Minister of Schooling and Education.
- The World Bank (WB) launched a Norland Innovation Initiative in collaboration with the Norland Innovation Fund. During the period a number of WB experts conducted assessments on technology and innovation needs in Norland and in follow-up several experts were designated to work with policymakers in the energy, transport infrastructure and telecommunications sectors. The Initiative concluded with a report to the Norland Innovation Fund.

  Several key figures describing STI in Norland up to 2012 are as follows:
  - 3.46 researchers per 1000 workers;
  - 0.5 patent applications per billion $ GDP (EU average is 4);
  - 0.4 PhD (doctoral) graduates per 1000 inhabitants (EU average is 1.5);

- 16% of the population aged 30-34 have completed tertiary education (EU average is 33.6%);
- R&D expenditure in the public sector is 0.18% of GDP (EU average is 0.76%) and has dropped from a high of over 0.2% in 2000;
- There are 6 active scientific institutions, independent from universities and predominantly engaged in applied research; all are dependent on government grants and projects and all employ less than 30 researchers each with salaries below those offered by private firms and experiencing a gradual reduction in available talent as many qualified STI graduates emigrate;
- There is a growing and generalized perception that engineering and/or technical education is hard field of study with poor income expectations, leading steadily to decreasing in enrolment in these studies;
- R&D expenditure by private firms as a per cent of firm revenues was less than 2%;
- Purchase of equipment or licenses (non-R&D innovation) was 0.9% of GDP (higher than the EU average of 0.7%);
- Employment in knowledge-intensive activities as % of total employment is 8% (below the EU average 0f 13.5%).

The Deputy Minister of Science and Technological Development was delegated to attend the UNCTAD Commission on Science and Technology held in May 2016 in Geneva. During informal discussions she recognized that many developed and increasingly developing and transition economies where working on improving their national innovation policies including through strengthening their “innovation systems” approach.

In order to review the state of the Norland *national system of innovation* and to diagnose and propose policies to strengthen it, upon return to the capital, the Ministry of Science and Technological Development has set up a team of experts to review potential policy options and actions.

You have been assigned to this team of experts. With other team members, you will be meeting representatives of other institutions-STI stakeholders in the near future. The outcomes of these meetings will feed back into the process for establishing a national innovation system policy. In preparation, you will develop an agenda for meeting with one or several institutions, assessing their goals, perspectives and capacities, and their relationships with other STI stakeholders.

In particular you will need to:

1. **Prepare a set of questions that would be the core working document for your discussions with the assigned institution(s);**
2. Develop an understanding of the STI landscape taking into consideration the goals, developments and data and identifying the role and importance of various STI stakeholders;
3. Develop several potential policies proposals aimed at strengthening the innovation system that will be discussed, clarified, substantiated or refuted in discussion with the institution(s) you will be meeting.

Key issues and pointers for the preparation of your questionnaire, brief and policy proposals and may be any of the following:

1. Balancing priorities:
- economic policy (short/medium term)
- development policy
- social policy
- environmental policy
- climate change (mitigation/adaption)
- vulnerability to natural catastrophes
- dependency on one or few economic sectors or products

2. Developing objectives:
- establish leadership
- communicate and legitimize policy
- establish and facilitate coordination
- develop common goals and understanding

3. Expanding the knowledge base:
- defining innovation system actors
- networking and collaboration, self-organization
- promoting knowledge relevant for innovation policy
- understanding incentives and disincentives
- defining governance and policymaking as a permanent learning process

4. Innovation systems as a horizontal policy:
- overcoming focus on narrow science and technology education objectives
- bringing into innovation strategy innovation and technology users – non-technology firms, households, communities, government, etc
- linking innovation to welfare – employment creation, public services, gender issues
- promoting collaboration between all innovation system stakeholders

5. Institution building:
- defining interface between innovation system agencies and policymakers (government offices and ministries)
- defining and delineating short- (agencies) and long-term (government) responsibilities
- defining interface with firms/private sector technology producers and users
- safeguarding learning from experience and institutional memory

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6. Public-private partnerships:
- stakeholder/joint investor relationships
- joint development of innovation clusters, innovation parks and business incubators
- partnerships in infrastructure development and information technology applications

7. Monitoring and reporting:
- precise targets, feedback and follow-through
- actions assigned to innovation system stakeholders are well defined, transparent and public
- contextualization against broader development policy framework and avoiding segmentation
- evaluation of achieved learning about the implementation of an innovation system

Innovation indicators for Norland		
	Relative to EU 27 average (=100)*	
ENABLERS	2010	2015
Human resources		
1.1.1 New doctorate graduates per 1000 population aged 25-34	30	35
1.1.2 Percentage population aged 30-34 having completed tertiary education	55	60
1.1.3 Percentage youth aged 20-24 having attained at least upper secondary level education	110	90
Research systems		
1.2.1 International scientific co-publications per million population	45	47
1.2.2 Scientific publications among the top 10% most cited publications worldwide as % of total scientific publications of the country	30	48
Finance and support		
1.3.1 R&D expenditure in the public sector as % of GDP	25	17
1.3.2 Venture capital (early stage, expansion and replacement) as % of GDP	5	8
FIRM ACTIVITIES		
Firm investments		
2.1.1 R&D expenditure in the business sector as % of GDP	25	48
2.1.2 Non-R&D innovation expenditures as % of turnover	115	125
Linkages & entrepreneurship		
2.2.1 SMEs innovating in-house as % of SMEs	85	102
2.2.2 SMEs collaborating with others on innovation as % of SMEs	50	35
2.2.3 Public-private co-publications per million population	6	3
Intellectual assets		
2.3.1 Patent applications per billion $ of GDP	15	45
2.3.2 Patent applications in climate change mitigation, health and sustainable energy, per billion $ of GDP	6	5
2.3.3 Community trademarks per billion $ of GDP	10	70
2.3.4 Community designs per billion $ of GDP	15	8
OUTPUTS		
Innovators		
3.1.1 SMEs introducing product or process innovations as % of SMEs	55	20
3.1.2 SMEs introducing marketing or organizational innovations as % of SMEs	50	35
Economic effects		
3.2.1 Employment in knowledge-intensive activities (manufacturing and services) as % of total employment	60	65
3.2.2 Medium and high-tech product exports as % total product exports	20	25
3.2.3 Knowledge-intensive services exports as % total service exports	17	50
3.2.4 Sales of new-to-market and new-to-firm innovations as % of turnover	105	135
3.2.5 License and patent revenues from abroad as % of GDP	2	0

* Data points are all relative to EU average (i.e. “45” means attained a level of 45% of the EU average, “135” means the indicator is 35% above the EU average).

The Ministry of Science and Technological Development decided it would follow the “Pro INNO EUROPE” methodology for innovation indicators.

Exercise 6. Evaluation - STI and NSI: General concepts and policy messages

The goal of exercise 6 is to provide feedback on the achievement of the course presentation and the accomplishments of the participants.

- Participants are requested to take an online multiple-choice test. The URL will be specified at the time of the course delivery.

- Participants are requested to write a 450-600 word discussion answering at least four but preferably all of the following questions:

    1. What is the role of science, technology and innovation in economic development?
    2. What is the relationship between innovation and invention?
    3. How does innovation affect firms, markets, or a national economy?
    4. What is the relationship between STI policies and a national system of innovation (NSI)?
    5. What are the key challenges of STI policy in your home country?
    6. Describe five STI policies that can address these key challenges?
    7. What is your evaluation of the applicability of an NSI framework to implement these policies and meet STI challenges in your country?

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