# NIS Diagnosis and STI Strategy Development to Achieve National Sustainable Development Goals

ESCAP Asian and Pacific Centre for Transfer of Technology (APCTT)

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*This publication was prepared under the overall supervision of Mr. Nagesh Kumar, Officer-in-Charge, APCTT-ESCAP, and the guidance of Mr. N. Srinivasan, Coordinator, Science, Technology and Innovation, APCTT-ESCAP, by Mr. Sunil Mani, National Graduate Institute for Policy Studies, Tokyo, Japan and Centre for Development Studies, Trivandrum, Kerala, India, the consultant engaged to prepare the contents of this publication.*

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# Abbreviations

| | | |
|---|---|---|
| EPO | : | European Patent Office |
| ESTs | : | Environmentally sound technologies |
| FTE | : | Full-time equivalent |
| GDP | : | Gross Domestic Product |
| GERD | : | Gross Domestic Expenditure on R&D |
| GVC | : | Global value chain |
| GSVCs | : | Government-sponsored venture capitalists |
| IPC | : | International Patent Classification |
| IPOs | : | Initial public offerings |
| IPR | : | Intellectual property rights |
| ISI | : | Institute for Scientific Information |
| IUS | : | Union Innovation Scoreboard |
| JPO | : | Japan Patent Office |
| JSTA | : | Japan Science and Technology Agency |
| LIUP | : | Local Industry Upgrading Programme |
| MNCs | : | Multinational corporations |
| NSB | : | National Science Board, the United States |
| NIS | : | National System of Innovation |
| OECD | : | Organisation for Economic Cooperation and Development |
| PCT | : | Patent Cooperation Treaty |
| PPP$ | : | Purchasing power parity in terms of US$ |
| PVCs | : | Private venture capitalists |
| R&D | : | Research and development |
| SCI | : | Science Citation Index |
| SDGs | : | Sustainable Development Goals |
| SITC | : | Standard International Trade Classification |
| SME | : | Small and Medium Enterprise |
| STI | : | Science, technology and innovation |
| TRIPS | : | Trade-Related Aspects of Intellectual Property Rights |
| UNCTAD | : | United Nations Conference on Trade and Development |
| UNESCO | : | United Nations Educational, Scientific and Cultural Organization |
| UNIDO | : | United Nations Industrial Development Organization |
| USPTO | : | United States Patent and Trade Mark Office |
| USSR | : | Union of Soviet Socialist Republics |
| VC | : | Venture capital |
| WIPO | : | World Intellectual Property Organization |

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# Abstract

This manual describes the process of adopting a National Innovation System (NIS) framework, and evolves strategies to strengthen the process of creating and diffusing new technologies and innovation within a nation state's economy. While innovation can be created without research, the increasing globalization has not reduced the importance of NIS framework in national economy. The framework maps out the institutions and incentive system that support technological change within a nation. Particular attention is paid to the interaction between the different actors or elements that constitute an NIS. The process of adoption of the NIS framework for identifying systemic failures that hamper the generation of innovation and its diffusion, and then correcting them so that innovative activity is promoted in a sustainable manner entails a series of five logical steps. The five steps are defining the core of the NIS, gathering data on innovative activity at the core, diagnosing health of the NIS by employing a variety of tried and tested innovation indicators, designing policy instruments to promote generation and diffusion of innovation, and finally evaluating the effectiveness of these policy instruments and making required corrections for optimizing their effectiveness. The manual would be very useful for policy makers working within the government ministries and institutions that support technological change, as well as to researchers in and students of the economics and policy regimes of technological change.

**Keywords**: National Innovation System, developing countries, innovation indicators, innovation policy, R&D, R&D tax incentives, patents, technology trade balance, policy, innovation surveys, evaluation.

# Chapter 1: Introduction

The National System of Innovation (NIS) concept had its origins at the end of the 1980s and middle of the 1990s (Freeman 1987, Lundvall 1992, Nelson 1993). Knowledge contains two dimensions: a "public" one, taking the shape of information easily codified in patents, blueprints, textbooks, etc.; and a "tacit" one, embodied in routines, skills, competencies, and specific practices (Nelson and Winter 1982, Polanyi 1967). The public aspect is costly to create but costless to transfer or to make available to others once it has been created. By contrast, the tacit one is not so easily transferred, being the result of different learning processes: learning by doing, by using, by searching, by imitation, by interaction, and by cooperation (Howells 2002). Because of this tacit aspect, new knowledge and innovations are partially context-specific and localized, thus calling for the introduction of geographical aspects. When the geographical distance is negligible, and the language and culture are common, the tacit aspects are easier to transfer. Given the importance of tacit knowledge in the creation of new knowledge and the difficulties in its transfer, an important interaction between space and innovation occurs. This has led to the development of descriptive frameworks like national, regional and even sectoral systems of innovation. The NIS, according to Lundvall (1992), is composed of elements and relationships involved in the production, diffusion and use of new economically useful knowledge that are located within the borders of a nation state. Differences in the NIS affect the direction or speed of the innovation of a nation and its national competitiveness.

The Sustainable Development Goals (SDGs), unanimously adopted by the United Nation's 193 Member States at a historic summit in September 2015, address the needs of people in both developed and developing countries, emphasising that no one should be left behind. While the SDGs are broad and ambitious in scope, they address the three dimensions of sustainable development – social, economic and environmental – as well as important aspects related to peace, justice and effective institutions. Science, technology and innovation (STI) are thought to play an important role in sustainable development. Besides this, the ninth goal is explicitly on promotion of innovation: "Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending". Adoption of the NIS framework for promoting innovation at the national level leads to achieving this target in a comprehensive and sustainable manner.

## Usefulness of the NIS Approach to Innovation as Compared with the Linear Approach

Innovation is now increasingly understood as the outcome of interactions among a number of actors or agents, such as the government, higher education institutes, research institutes and business enterprises, located within a nation's economy. Discordance in the system, namely in the interactions among the various elements, can reduce the overall rate of innovations, as measured using indicators such as research and development (R&D) expenditure and patents. Adoption of an

NIS framework to innovations can help identify systemic failures, which can then be corrected through public policy instruments. For example, innovative activity by business enterprises may decrease between two time points. In the conventional perspective (that is, linear innovation), this reduction is interpreted as reduction in the incentive to innovate by business enterprises. This diagnosis leads policy makers to design various types of financial instruments, such as tax incentives, which can reverse this decline in investments in R&D. However, the decline in innovative activity may actually be due to another factor, such as the business enterprises being unable to get adequate scientists and engineers to perform R&D activities. This in turn may be due to the higher education sector not generating enough scientists and engineers of the right quality and numbers to be employed as R&D scientists in business enterprises. A system of innovation perspective will be able to detect these apparent discordances between various agents more effectively and then, as stated before, make corrections through appropriate public policy action. In the example given above, the correct policy response will be to improve the quantity and quality of students graduating in science and engineering subjects rather than merely providing tax incentives to business enterprises. This understanding of the linkages among the actors involved in innovation is key to improving technology performance.

It should, however, be mentioned that individuals (not affiliated to any business enterprises or institutions) are important originators of new ideas that sometimes fructify into new products and new production methods. This is sometimes referred to as grassroots innovations and they are very often community-led innovations for sustainability, which have originated from a felt need for certain products and services under severe financial and material constraints. The main problem with grassroots innovations is that they hardly get diffused. Adopting an NIS framework can lead to the development of these grassroots innovations, as institutions that can support their evolution can be readied and put in place.

In practical terms, adoption of the NIS framework to policy making can reduce the distance that the developing countries in general, and those in the Asia-Pacific in particular, have to travel to climb up the ladder of technological capability. Table 1 presenting the number of United States patents granted to developing countries captures the fact that developing countries are too far away from the technology frontier. If we keep out the Republic of Korea and Taiwan Province of China, the share of developing countries drops down to insignificance.

## Definitions of NIS

A number of definitions of the concept of NIS are available. In the literature, one encounters at least four definitions of it attributable to four economists whose names are intimately linked to the genesis of this framework and its eventual diffusion among innovation studies practitioners and researchers. Let us consider each of these definitions:

Definition 1 (Freeman 1987): "…the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies".

Definition 2 (Lundvall 1992): "...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."

Definition 3 (Nelson 1993): "…a set of institutions whose interactions determine the innovative performance… of national firms" and most important institutions are those supporting R&D efforts.

Definition 4 (Metcalfe 1997): "…that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such, it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies."

Definition 5 (Niosi and Bellon 1994): "A national system of innovation is 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 those units may be technical, commercial, legal, social and financial, inasmuch as the goal of the interaction is the development, protection, financing or regulation of new technology".

**Table 1: Trends in the share of developing countries in total patents granted by the USPTO: 1990-2010**

| Year | Patents granted | Share of patents (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Foreign patents | Developing country patents | Republic of Korea | Taiwan Province, China | People's Republic of China | India | Developing countries excl.the four |
| 1990 | 99220 | 46.61 | 1.66 | 0.29 | 0.87 | 0.05 | 0.02 | 0.43 |
| 1991 | 106840 | 45.91 | 1.92 | 0.42 | 1.03 | 0.05 | 0.02 | 0.40 |
| 1992 | 107511 | 45.32 | 2.13 | 0.55 | 1.17 | 0.04 | 0.02 | 0.36 |
| 1993 | 109890 | 44.29 | 2.60 | 0.76 | 1.37 | 0.05 | 0.03 | 0.39 |
| 1994 | 113704 | 43.41 | 2.98 | 0.89 | 1.60 | 0.04 | 0.02 | 0.43 |
| 1995 | 113955 | 43.39 | 3.43 | 1.09 | 1.83 | 0.06 | 0.03 | 0.43 |
| 1996 | 121805 | 43.01 | 3.76 | 1.29 | 1.99 | 0.04 | 0.03 | 0.42 |
| 1997 | 124147 | 43.68 | 4.23 | 1.58 | 2.09 | 0.05 | 0.04 | 0.47 |
| 1998 | 163205 | 44.43 | 4.96 | 2.06 | 2.33 | 0.05 | 0.06 | 0.45 |
| 1999 | 169145 | 44.37 | 5.46 | 2.18 | 2.68 | 0.06 | 0.07 | 0.48 |
| 2000 | 176083 | 44.91 | 5.95 | 1.97 | 3.30 | 0.09 | 0.07 | 0.52 |
| 2001 | 184046 | 46.40 | 6.37 | 2.04 | 3.56 | 0.14 | 0.10 | 0.52 |
| 2002 | 184424 | 47.34 | 6.72 | 2.17 | 3.65 | 0.21 | 0.14 | 0.54 |
| 2003 | 187048 | 47.29 | 6.77 | 2.21 | 3.57 | 0.23 | 0.19 | 0.57 |
| 2004 | 181320 | 48.09 | 7.63 | 2.58 | 3.97 | 0.33 | 0.21 | 0.55 |
| 2005 | 157741 | 47.64 | 7.86 | 2.91 | 3.80 | 0.36 | 0.26 | 0.53 |
| 2006 | 196437 | 47.94 | 8.65 | 3.31 | 4.03 | 0.49 | 0.26 | 0.55 |
| 2007 | 182928 | 48.78 | 9.64 | 3.97 | 4.10 | 0.68 | 0.32 | 0.59 |
| 2008 | 185244 | 50.34 | 10.92 | 4.71 | 4.20 | 1.01 | 0.36 | 0.63 |
| 2009 | 191933 | 50.48 | 11.25 | 4.98 | 4.05 | 1.18 | 0.38 | 0.65 |
| 2010 | 244358 | 50.41 | 11.56 | 5.12 | 3.94 | 1.35 | 0.47 | 0.68 |

*Source: Szirmai 2015*

## Four Insights from the Definitions of NIS

The NIS approach draws our attention to *four* insights. These are:

**Sources of innovation:** The NIS approach stresses the importance of non-R&D routes to innovation. This means that innovation is not really the outcome of intramural R&D alone, but also comes through a variety of non-R&D routes such as purchase of capital goods or machinery, training of technicians, extramural R&D and purchase of software. These non-R&D routes are revealed through successive innovation surveys conducted in Europe, Latin America and, indeed, Asia as well. Given the fact that most firms in developing countries are of the Small and Medium Enterprise (SME) type, this insight on non-R&D routes are most helpful in understanding the innovative activity of such firms as they rarely have intramural R&D activities.

**Actors:** An NIS consists of a number of actors, broadly classified into narrow and broad sets. In the narrow context, these actors consist firstly of governments (local, regional and national) that play the key role in setting broad policy directions. Secondly, there are bridging actors such as research councils and research associations, which act as intermediaries between governments and performers of research. Business enterprises that the other actors finance to carry out R&D and other innovation generating activities make up the last category. The broader set of actors include, in addition to the components within the narrow NIS, all economic, political and social institutions affecting learning, searching and exploring activities such as the nation's financial system; its monetary policies; internal organization of business enterprises; the education systems; labour markets; and regulatory institutions. It is argued that a country's innovative performance largely depends on how these actors relate to each other as elements of a collective system of knowledge creation and use. For example, government research institutes, higher education institutions and business enterprises serve as research producers performing R&D activities. On the contrary, governments, whether federal or regional, play the role of coordinators among research producers in terms of their policy instruments, visions and future perspectives. In order to promote innovation, the different actors must have strong linkages with each other based on a robust level of trust, and governments should promote and activate trust among these actors.

**Role of institutions:** Institutions are central to the NIS concept, as they provide structure to as well as insights in the way in which actors behave within the system. There are two types of institutions: tangible and intangible. Tangible institutions include organizations that support technological change in a nation (such as government research institutes), industrial standards and metrology, technology financing and technology forecasting institutions, etc. Intangible ones include rule of law, property rights, habits and practices, routines, etc. and how innovation comes about and is perceived. Edquist and Johnson (2000) present taxonomy of the different types of institutions that matter for innovation systems on the basis of characteristics such as formal versus informal, basic versus supportive, hard versus soft, and consciously or unconsciously designed.

**Interaction and Interactive learning:** A common feature of all innovation systems is the fact that firms rarely, if ever, innovate alone. There is always constant cooperation and interaction by an innovating firm and its external environment, which can lead to better exploitation of available knowledge. Nelson (1993) makes an important statement to this effect: "to orient R&D fruitfully, one needs detailed knowledge of its strengths and weaknesses and areas where improvements would yield big payoffs, and this type of knowledge tends to reside with those who use the technology, generally firms and their customers and suppliers. In addition, over time firms in an industry tend to develop capabilities… largely based on practice".

## Relevance of NIS Framework in the Context of Innovation without Research and Globalisation of Innovation

The relevance of the NIS framework is under some threat or erosion [as Soete and others (2010) referred to] on account of two reasons. The first threat comes from knowledge service activities, which lead to innovation without research. Firms could innovate by accessing information on the Internet. Faster diffusion of broadband is facilitating this and has resulted in open flows of information. There are a number of firms from the Asia-Pacific region which have become important leaders in their industrial sectors and these firms reached their respective exalted position without doing formal R&D. Examples of these types of non-R&D innovation are Malaysian firm such as Top Glove (which is one of the largest rubber glove making firm in the world) and the Indonesian firm Bukaka (which is one of the leading passenger boarding bridge manufacturers in the world). The second threat has come from the globalisation of innovation. Although the globalisation of innovation is contested in empirical terms as overwhelming majority of innovations are performed in the home countries of multinational corporations (MNCs), there is now growing evidence to show that an increasing number of MNCs are decentralising their R&D activities and performing innovative activities in foreign locations away from their respective home countries. If foreign owned firms increasingly do innovative activity in a country, then national policies and institutions that support technological change are expected to have a lesser impact or no impact at all. If this line of reasoning is correct, then the relevance of the NIS framework when technology is globalising is under some strain. However, as Freeman (1993) argues, "their importance derives from the networks of relationships which are necessary for any firm to innovate. Whilst external international connections are certainly of growing importance, the influence of the national education system, industrial relations, technical and scientific institutions, government policies, cultural traditions and many other national institutions is fundamental". The historical examples of Germany, Japan and the former Union of Soviet Socialist Republics (USSR) illustrate this point, as well as the more recent contrast between East Asian and Latin American countries.

Another dimension of globalisation of innovation is the emergence and rapid growth of global value chain (GVC), where the different stages of the production process are located across different countries. Globalisation motivates companies to restructure their operations internationally through outsourcing and off-shoring of activities. Firms try to optimise their production processes by locating the various stages across different sites. The past decades have witnessed a strong trend towards the international dispersion of value chain activities such as design, production, marketing, distribution, etc. This emergence of GVCs challenges conventional wisdom on how innovations are created. Participation in GVCs can result in transfer of technology from developed to developing countries, and hence the NIS can have a role in enabling the recipient firm in the developing world which is inserted in to the GVC to absorb the transferred technology, develop local capabilities and then to move up the value chain in terms of technological sophistication. With strong policy support, such contract manufacturers can graduate themselves from being mere assemblers to having their own design and manufacturing their own brand. This graduation is only possible if the NIS is geared to enabling the firm to develop strong technological capabilities. This is not a mere theoretical argument. Practical examples can be given from the Republic of Korea where the now electronics and telecommunications giant, Samsung, has graduated from being a mere contract manufacturer to becoming one of the most innovative business enterprises in the world: during the five year period 2010-14, Samsung had 24017 patents granted to it at the United States Patent and Trade Mark Office (USPTO). That it was able to do so was to a great extent facilitated by a strong Korean NIS where the interactions between the various actors such as universities, research institutes, firms and the government were very strong and in an optimal state. Such interactions remain robust, enabling the electronics and automotive firms in the Republic of Korea to maintain their technological leadership on a continuous basis.

## NIS and Open Innovation

The concept of open innovation enunciated by the management guru, Henry Chesbrough, has many parallels with the NIS framework. Open innovation is defined as the process of innovating in partnership with those outside one's company by sharing the risks and rewards of the outcome and process. Thus in open innovation, the firm or the business enterprise use both internal and external ideas to generate innovations of its own. In this process, open innovation requires the innovation-generating enterprises to interact with other actors in the so-called ecosystem for innovation. The interactions are mostly with other firms but also with institutions as well.

The main advantages of open innovation are:

- Reduced cost of conducting research and development;
- Potential for improvement in development productivity;
- Incorporation of customers early in the development process;
- Increase in accuracy for market research and customer targeting; and
- Potential for synergism between internal and external innovations.

The main disadvantages of open innovation are:

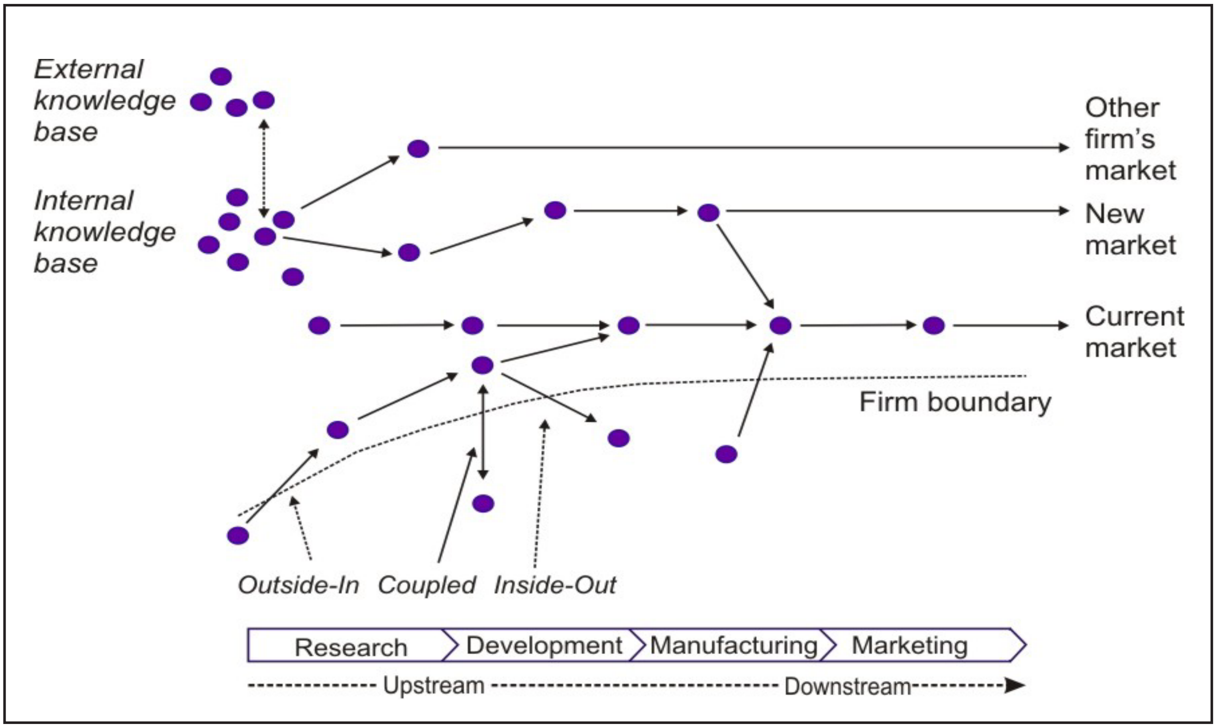
- Possibility of revealing information not intended for sharing;
- Potential for the hosting organization to lose their competitive advantage as a consequence of revealing intellectual property;
- Increased complexity of controlling innovation and regulating how contributors affect a project;
- The need for devising a means to properly identify and incorporate external innovation; and
- The need for realigning innovation strategies to extend beyond the firm in order to maximize the return from external innovation.

However, from experience the partnering usually takes place between a large firm and start-ups where the large firm provides the start-ups with all support to incubate their new ideas. So the open innovation case is a special case of creating an NIS. But the idea can be tried out with SMEs partnering with themselves to create new technologies.

The two main characteristics of open innovation are the utilization of knowledge that is both inside and outside the firm to innovate something new and therefore the knowledge utilized in the innovation and the knowledge resulting from the innovation are able to permeate both inside and outside of firm's organizational boundaries.

Literature (Chesbrough and Bogers 2014) has identified three types of open innovation. These are Outside-in (or inbound); Inside-out (or outbound); and Coupled open innovation (See Figure 1).

**Figure 1: The Open Innovation Model**




*Source: Chesbrough and Bogers (2014), p. 18*

The figure shows different paths that knowledge or technology may follow within and across boundaries of the firm. It also extends the open innovation model from upstream R&D to manufacturing and marketing to thereby highlight the importance of more downstream activities in the overall innovation process, as well as to emphasize the importance of considering all activities from invention to commercialization in order to capture values from ideas and technologies. The Outside-In type of open innovation involves opening up a company's own innovation processes to many kinds of external inputs and contributions, for example, through acquiring or sourcing. The Inside-Out type of open innovation requires organizations to allow unused and under-utilized ideas and assets to go outside the organization for others to use in their businesses and business models. The third or coupled type of open innovation involves combining purposive inflows and outflows of knowledge to collaboratively develop and commercialize an innovation.

# Chapter 2: Operationalizing the NIS Framework for Policy Purposes

The most important use of adopting the NIS framework stems from its potential for identifying systemic failures and then correcting them with appropriate policy interventions. According to Soete and others (2010), the NIS framework provides a much broader foundation for policy in comparison with the traditional market failure-based policy perspective. In the latter perspective, every policy measure must be justified by the identification of some sort of market failure and by an argument that explains how the policy can bring the system closer to its optimal state. This means that not all market failures make out a case for government interventions. Owing to the variety of institutions supporting technological change and to the multi-dimensional nature of innovation, the innovation systems approach rejects the idea of an optimal state of the system as a target for policy to achieve. The set of instruments for innovation systems policy includes all instruments that are traditionally in the domain of science and technology policy and also education policy. Further, industrial, trade and regional policies too are important ingredients in innovation systems policies.

## Steps Involved in Operationalizing the NIS Framework for Policy Purposes

The first step involved in applying the NIS framework for policy purposes is to identify the core of the system, and the next step is to identify the interactions that the core is having with rest of the system. The third step would be to measure the health of a nation's system of innovation using a range of conventional and new innovation indicators The fourth step would be to design various policy instruments for promoting innovations, increasing the absorptive capacity of the core, engineering positive spillovers to local firms from foreign companies, etc. The fifth and final step involves evaluating the effectiveness of these policy instruments to stimulate innovations. Such an evaluation will enable the country in question to effect some mid-course correction. We will now discuss each of these steps in some detail. However, before doing so, a review of the existing methodologies for similar diagnostic exercises will be helpful.

## An Engagement with the Literature on Existing Diagnostic Exercises

There are two different classes of diagnostic exercises that are available. The first one is at the international level conducted by multilateral agencies such as the United Nations and the Organisation for Economic Cooperation and Development (OECD) and these usually cover a range of countries. Mention should also be made of quinquennial UNESCO Science Reports – published by the United Nations Educational, Scientific and Cultural Organization (UNESCO) – which too contains detailed assessment of the innovative health of several nations. While the report does not explicitly use the NIS framework, it does provide a comprehensive diagnosis of the innovative activities across a large number of countries over a five-year horizon. Each of the country studies clearly concludes with a list of tangible areas that need some policy attention. The second one is more at the national level by national governmental agencies such as the National Science Board in the United States or the European Commission for the nations in the European Union.

We will first consider the multilateral class of diagnostic studies. The two dominant approaches here are those by the United Nations Conference on Trade and Development (UNCTAD) through its *Science, Technology and Innovation Policy Reviews* (STIP Reviews) and OECD through its *Reviews of Innovation Policies* (OECD-RIP) of both member and non-member countries. UNCTAD has conducted 13 STIP reviews between 1999 and 2015 covering such countries as Colombia, Mauritania, Jamaica, Islamic Republic of Iran, Angola, Lesotho, Peru, Ghana, El Salvador, Dominican Republic, Oman and Thailand. On the contrary, OECD has conducted reviews of innovation policies of 11 developing countries such as China, Chile, Colombia, Mexico, Peru, South Africa, Cambodia, Vietnam, Indonesia, Malaysia and Singapore. Both these reviews use a similar methodology of describing the institutions and policy instruments that support technological change in the chosen countries. Although the first STIP Reviews were done in 1999, a document outlining the framework for analysis was published only in 2011. According to it, "The typical structure of a STIP Review report consists of an introductory chapter, a chapter dealing with the NSI, one or more chapters of analysis at the sector level, and a closing chapter that presents the key recommendations emanating from the STIP Review". However, the actual contents of individual country reviews have varied. Nevertheless, the STIP Reviews are useful in gaining an understanding of the institutions that support technological change in the countries and the policy instruments for stimulating innovations. As the reviews do not identify the core of the NIS, the policy prescriptions given tend to be very general such as improving the education system, enhancing the interaction between firms and universities, etc. It is also not clear whether after the conduct of these reviews the countries reviewed have been able to correct for the identified systemic failures. The OECD-RIP reports are more focused on the policy instruments for strengthening innovative activity in a nation state. It is an important source of information on the NIS of specific countries and also tracks the changes in the NIS of a country over time. For instance, the report on the People's Republic of China maps out in a succinct manner the evolution of the Chinese NIS from the government being at the core earlier to business enterprises being at the core at present. Although both the diagnostic exercises are very rich in details, they are more descriptive than analytical. For instance, there is no systematic analysis of the relationship between policy interventions and policy outcomes discussed in these exercises. Further, the reports also do not consider in detail the results of innovation surveys conducted in the selected countries. These are the gaps that are sought to be filled in by the present manual, which takes the practitioner through various steps involved in implementing the NIS framework for policy purposes.

The most important country-level assessment of innovative activity is done by the United States National Science Board (NSB) through the biennial publication *Science and Engineering Indicators*. The report measures and bench marks the health of the United States' science and engineering sectors in a comparative fashion. The report has eight chapters of which three deal with human resources in science and engineering, three with innovative activity in both academia and business enterprises, and one chapter each deals with public attitude and understanding of science and with innovative activity across the states in the country. Although the report does not explicitly claim to be using an NIS framework, it does use one and provides a comprehensive survey of the science and engineering health of the country. It also makes liberal use of many innovation indicators to measure the health of the nation's NIS. It is by far the most comprehensive diagnostic exercise undertaken at the level of an individual country and also has been brought out regularly since 1993. An interesting aspect of this exercise is a comparative analysis of innovative activity, which makes eminent sense in an increasingly globalised innovation activity. A similar exercise across the European Union countries is termed as Union Innovation Scoreboard (IUS). The IUS provides an annual comparative assessment of the research and innovation performance of the European Union member states and the relative strengths and weaknesses of their research and innovation systems.

It helps member states assess areas in which they need to concentrate their efforts in order to boost their innovation performance. In addition, the Scoreboard also covers Serbia, the Republic of Macedonia, Turkey, Iceland, Norway and Switzerland. On a smaller set of indicators, available internationally, it also covers Australia, Brazil, Canada, People's Republic of China, India, Japan, Russia, South Africa, Republic of Korea and the United States. The IUS distinguishes between three main types of indicators – Enablers, Firm Activities and Outputs – and eight innovation dimensions, capturing in total 25 indicators. An interesting aspect of the exercise is that it places firms at the core of the NIS.

In the light of the above engagement with the literature on NIS diagnosis, this manual proposes a framework that combines useful elements from the above exercises. The uniqueness of this manual lies in logically sequencing the steps so that systemic failures are more easily and correctly identified and policy measures to correct for them readily suggested. We will begin by elaborating on these logically sequenced series of five steps.

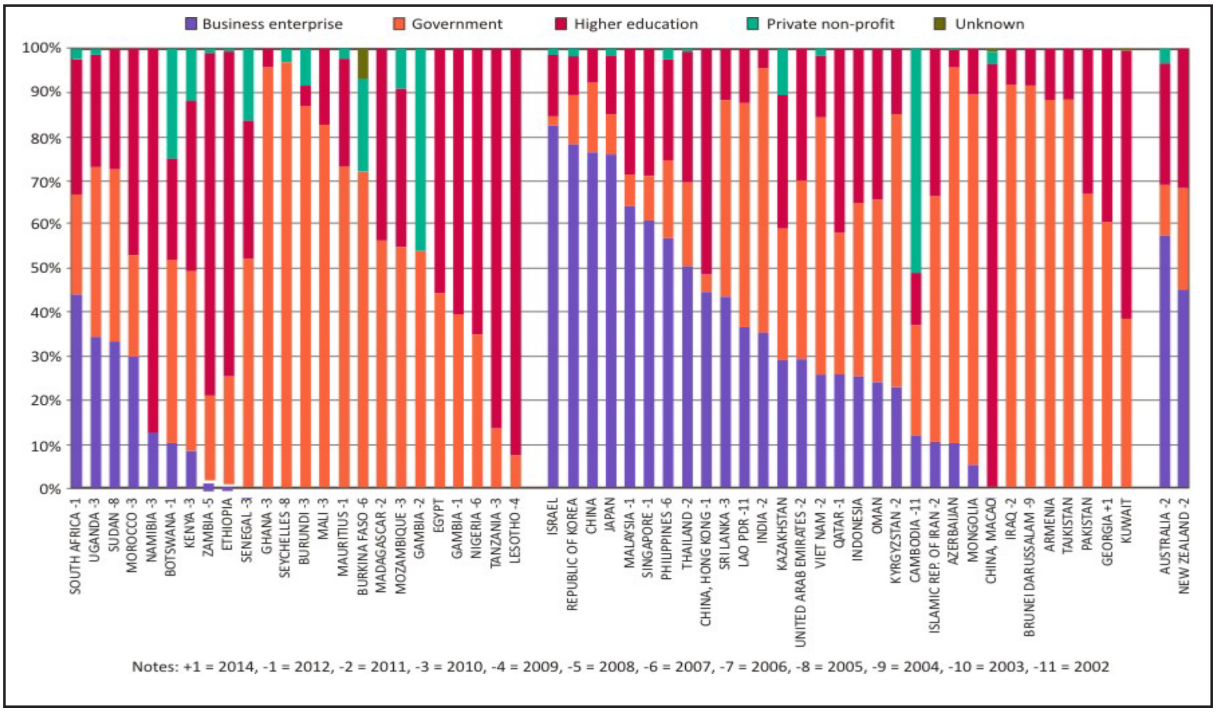
## The Five Steps

### Step 1: Defining the Core of the System

It is very important to identify the core of the NIS. The core is defined as that actor which generates most of the innovations in a nation state. The candidates for the core are government research institutes, universities and business enterprises that are normally in the private sector but can also be in the public sector as is the case in a number of developing countries. This step would involve quantifying the amount of innovations performed in a nation state. The most easily and universally available indicator to quantify innovations occurring in a country are best captured by the input to that activity. This is best represented by the Gross Domestic Expenditure on R&D (GERD). From the relative share of the various actors, one can then identify the core. As the NIS core can, of course, vary from one country to another, we have identified the core in a number of countries across the four continents. This is illustrated in Figures 2a, 2b and 2c. The data for this exercise were sourced from UNESCO Institute of Statistics (2015).

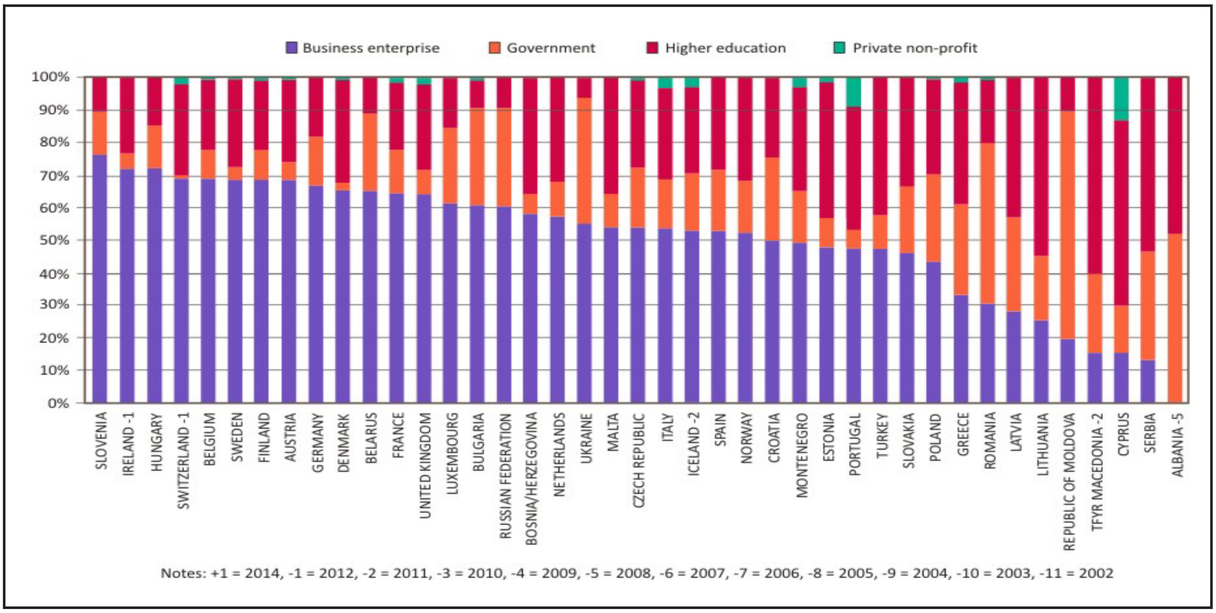
Two important inferences can be drawn from these figures: (1) business enterprises form the core of the NIS in most countries in Asia, Americas and Europe, while government is at the core in most African nations, except the more developed South Africa; and (2) almost all countries that are at the top of the technological capability ladder – like Japan, the Republic of Korea, Germany, the United States and the People's Republic of China – have business enterprises very much at the core of their NISs. In some of these countries such as the Republic of Korea and the People's Republic of China, the core has moved towards business enterprises in the more recent period. Most dramatic is the case of the People's Republic of China where the NIS has evolved in the last ten years or so, with the business enterprises becoming the core of the NIS. It is seen that the countries tend to be

**Figure 2a: Distribution of GERD across various actors in the NIS in Africa and Asia**



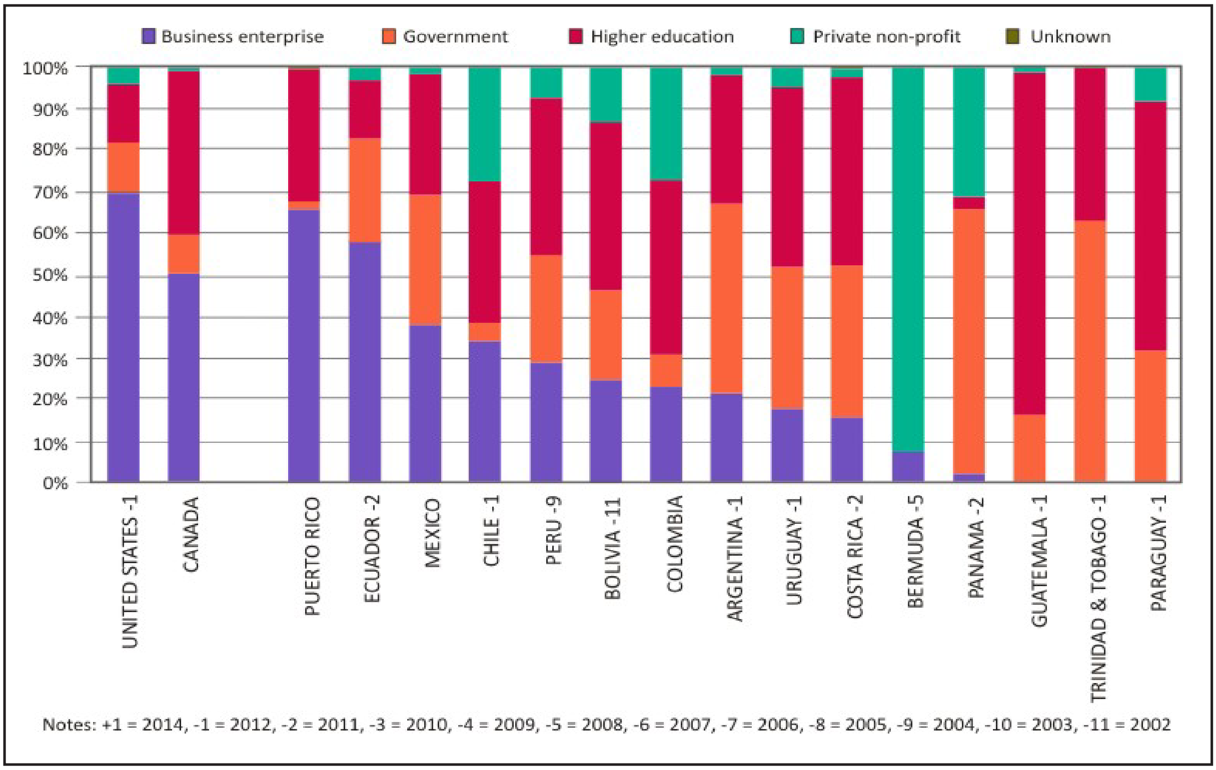

*Source: UNESCO Institute of Statistics (2015b)*

**Figure 2b: Distribution of GERD across various actors in the NIS in Europe**




*Source: UNESCO Institute of Statistics (2015b)*

**Figure 2c: Distribution of GERD across various actors in the NIS in the Americas**




*Source: UNESCO Institute of Statistics (2015b)*

more innovative when the locus of manufacturing and innovative activity resides with the same actor. Conversion of research results to commercialisable products and processes is quicker when business enterprises, rather than the government, do much of the R&D on their own. This, of course, does not mean that the government is not important in innovative activity; it only means that government by itself is not an important player in the performance of R&D, but it incentivises business enterprises to do R&D and other innovative activity through the provision of a variety of financial incentives.

## Step 2: Gathering Data on Innovative Activities of the Core

We have now demonstrated that **the core of an innovation system** is essentially the business sector. The precise nature of the core may vary from one nation to another. As a general rule of thumb, the more developed a country is, the more the probability for business enterprises (whether public or private) being at the core. Government is still at the core of the NIS for most less developed countries, where most of the firms are in the unorganised sector. However, the term NIS presupposes that there exists a range of actors – government, business enterprises, higher education system and other technology supporting institutions – that interact with each other to produce new products and processes that we call innovation. An empirical finding that supports this argument is that all those countries that are innovative or are fast becoming innovative – such as Japan, the Republic of Korea, Taiwan Province of China, Singapore, the People's Republic of China and India – have business enterprises at their core. Of course, it is not argued here that business enterprises becoming the core would automatically enable a country to be more innovative. This depends of course on the interaction of the core with rest of the system.

The next step would be to gather data on innovative activities by the core. This is usually accomplished through innovation surveys (See Box 1) which were initially devised by the European Union, but has now spread to almost 64 countries in the world. Many Asia- Pacific countries – such as the People's Republic of China, India, Indonesia, Malaysia, the Philippines, the Republic of Korea and Japan – have done at least one round of innovation surveys. Through the innovation surveys, the business enterprises that have performed at least one of the following types types of innovation – product, process, organizational and marketing innovations – have been identified (Table 2).

**Table 2: Innovating business enterprises in low and middle-income countries (as a percentage of manufacturing firms)**

| Country | Product innovators | Process innovators | Organizational innovators in manufacturing | Marketing innovators |
|---|---|---|---|---|
| Argentina | 31.7 | 29.5 | 13.3 | 8.7 |
| Belarus | 22.9 | 5.9 | 2.5 | 3.9 |
| Brazil | 17.5 | 32.0 | 57.8 | 42.9 |
| Bulgaria | 14.3 | 13.2 | 11.8 | 13.1 |
| People's Republic of China | 25.1 | 25.3 | - | - |
| Colombia | 17.1 | 22.1 | 13.4 | 9.4 |
| Costa Rica | 67.5 | 62.1 | 40.4 | 43.0 |
| Cuba | 44.0 | 48.4 | 64.8 | 23.2 |
| Ecuador | 45.8 | 47.1 | 21.0 | 29.0 |
| Egypt | 6.1 | 8.3 | 3.7 | 6.5 |
| El Salvador | 23.3 | 18.9 | 9.6 | 10.7 |
| Hungary | 13.1 | 9.5 | 13.0 | 16.2 |
| India | 12.1 | 12.1 | 38.0 | 35.5 |
| Indonesia | 20.2 | 18.1 | 39.0 | 55.2 |
| Kenya | 40.3 | 32.8 | - | - |
| Malaysia | 43.6 | 44.1 | 37.7 | 50.2 |
| Mexico | 9.7 | 6.8 | 3.2 | 1.8 |
| Nigeria | 50.1 | 58.6 | - | - |
| Panama | 36.6 | 36.6 | - | - |
| Philippines | 37.6 | 43.9 | 57.8 | 50.4 |
| Romania | 12.1 | 13.1 | 16.9 | 18.8 |
| Serbia | 36.6 | 35.1 | 39.0 | 37.4 |
| South Africa | 16.8 | 13.1 | 52.6 | 23.3 |
| Tanzania | 61.3 | 27.0 | - | - |
| Turkey | 26.2 | 29.5 | 23.9 | 38.4 |
| Uganda | 61.1 | 63.1 | - | - |
| Ukraine | 11.0 | 11.6 | 10.0 | 13.8 |

*Source: UNESCO Institute of Statistics (2015a)*

Further, there is also discussion on the routes to innovation and the surveys pick up particularly the non-R&D routes to innovation – such as acquisition of machinery, equipment and software; acquisition of external knowledge; training; market introduction; etc. (Table 3) – and on the linkages that business enterprises have with rest of the NIS. The linkages are, in turn, in terms of sources of information on innovation (Table 4) and the cooperation that business enterprises have with other organizations – other business enterprises or non-commercial institutions (Table 5).

**Table 3: Business enterprises that engaged in innovation activities (as a percentage of innovation-active manufacturing firms)**

| Country | In-house R&D | Contracted out R&D | Acquisition of machinery, equipment & software | Acquisition of external knowledge | Training | Market introduction of innovation | Other preparations |
|---|---|---|---|---|---|---|---|
| Argentina | 71.9 | 19.3 | 80.4 | 15.1 | 52.3 | - | 51.4 |
| Belarus | 26.4 | 18.0 | 61.0 | 0.9 | 13.8 | 9.6 | 55.4 |
| Brazil | 17.3 | 7.1 | 84.9 | 15.6 | 62.8 | 33.7 | 33.8 |
| Bulgaria | 13.8 | 7.0 | 65.8 | 14.5 | 29.4 | 23.2 | 28.7 |
| People's Republic of China | 63.3 | 22.1 | 66.0 | 28.1 | 71.5 | 60.6 | 36.9 |
| Colombia | 22.4 | 5.8 | 68.6 | 34.6 | 11.8 | 21.4 | - |
| Costa Rica | 76.2 | 28.3 | 82.6 | 38.9 | 81.2 | - | 75.9 |
| Cuba | 9.8 | 41.3 | 90.2 | 36.6 | 22.1 | 83.8 | 11.9 |
| Ecuador | 34.8 | 10.6 | 74.5 | 27.0 | 33.7 | 10.6 | 10.1 |
| Egypt | 39.3 | 5.4 | 66.1 | 9.8 | 52.7 | 17.9 | 33.9 |
| El Salvador | 41.6 | 6.7 | - | - | - | 82.7 | - |
| Ghana | 42.1 | 14.0 | 80.7 | 15.8 | 86.0 | 71.9 | 45.6 |
| Hungary | 51.4 | 25.2 | 66.2 | 20.0 | 34.3 | 23.8 | 38.0 |
| India | 35.5 | 11.4 | 67.6 | 16.1 | 39.2 | 16.7 | 14.8 |
| Indonesia | 58.4 | 6.2 | 47.8 | 27.0 | 46.5 | 59.3 | 94.2 |
| Kenya | 44.1 | 40.9 | 89.2 | 50.5 | 91.4 | 73.1 | 68.8 |
| Malaysia | 69.3 | 17.4 | 59.8 | 21.9 | 71.4 | 48.1 | 64.5 |
| Mexico | 42.9 | 14.5 | 35.4 | 2.6 | 12.5 | 11.4 | 18.0 |
| Morocco | 60.3 | 39.7 | - | - | - | - | - |
| Nigeria | 48.8 | 30.7 | 82.9 | 51.7 | 81.2 | 61.0 | 40.5 |
| Panama | 11.4 | 4.7 | 32.2 | 8.5 | 10.0 | - | 5.2 |
| Romania | 37.4 | 10.1 | 75.4 | 12.7 | 34.2 | 37.6 | 27.7 |
| Serbia | 59.9 | 26.2 | 76.1 | 20.1 | 51.6 | 51.3 | 34.5 |
| South Africa | 54.1 | 22.4 | 71.2 | 24.8 | 69.6 | 42.6 | 47.7 |
| Tanzania | 39.3 | 27.4 | 79.8 | 51.2 | 96.4 | 64.3 | 53.6 |
| Turkey | 33 | 11.6 | 53.3 | 14.4 | 43.1 | 49.1 | 41.2 |
| Uganda | 60.1 | 34.5 | 68.5 | 39.9 | 73.7 | 56.0 | 41.5 |
| Ukraine | 23.6 | 9.9 | 73.2 | 9.7 | 20.3 | 14.0 | 23.2 |

*Source: UNESCO Institute of Statistics (2015a)*

**Table 4: Business enterprises that rated sources of information as highly important (as a percentage of innovation-active manufacturing enterprises)**

| Country | Internal | Market | | | | Institutional | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Within the enterprise/ group | Suppliers of equipment, machinery | Clients or customers | Competitors | Consultants | Universities | Goverment research institutes | Confer-ences trade fairs exhibitions | Scientific journals | Profes-sional, industry associations |
| Argentina | 26.4 | 52.7 | 36.3 | 16.4 | 28.5 | 40.0 | 42.4 | - | - | - |
| Brazil | 41.3 | 41.9 | 43.1 | 23.8 | 10.2 | 7.0 | - | - | - | - |
| Bulgaria | 28.6 | 22.4 | 26.1 | 13.6 | 5.5 | - | - | 13.6 | 9.4 | 5.1 |
| People's Republic of China | 49.5 | 21.6 | 59.7 | 29.6 | 17.1 | 8.9 | 24.7 | 26.7 | 12.0 | 14.8 |
| Colombia | 97.6 | 42.5 | 52.6 | 32.1 | 28.4 | 16.2 | 8.0 | 43.7 | 47.3 | 24.5 |
| Cuba | 13.6 | - | 11.5 | 5.1 | - | 19.6 | 24.7 | - | - | - |
| Ecuador | 67.0 | 34.9 | 59.0 | 27.1 | 10.7 | 2.0 | 2.2 | 22.2 | 42.5 | 6.3 |
| Egypt | 75.9 | 32.1 | 16.1 | 17.0 | 2.7 | 1.8 | 0.9 | 22.3 | 13.4 | 4.5 |
| El Salvador | - | 26.4 | 40.3 | 5.4 | 15.2 | 3.8 | 1.8 | 13.9 | 10.3 | - |
| Ghana | 43.9 | 29.8 | 35.1 | 17.5 | 5.3 | - | 3.5 | 14.0 | 7.0 | 14.0 |
| Hungary | 50.5 | 26.4 | 37.4 | 21.3 | 13.0 | 9.9 | 3.3 | 16.6 | 9.6 | 7.7 |
| India | 58.5 | 43.3 | 59.0 | 32.6 | 16.8 | 7.9 | 11.0 | 29.7 | 15.1 | 24.5 |
| Indonesia | 0.4 | 1.3 | 1.8 | 1.3 | 0.9 | 0.4 | 0.4 | 0.9 | 0.9 | 0.9 |
| Kenya | 95.7 | 88.2 | 90.3 | 80.6 | 52.7 | 37.6 | 39.8 | 71.0 | 64.5 | 72.0 |
| Malaysia | 42.4 | 34.5 | 39.0 | 27.9 | 15.0 | 9.5 | 16.7 | 28.1 | 21.7 | 23.6 |
| Mexico | 92.2 | 43.6 | 71.9 | 44.0 | 19.0 | 26.4 | 23.6 | 36.9 | 24.5 | - |
| Morocco | - | 51.3 | 56.4 | 15.4 | 17.9 | 6.4 | 12.8 | 43.6 | 34.6 | 25.6 |
| Nigeria | 51.7 | 39.3 | 51.7 | 30.0 | 14.6 | 6.8 | 4.1 | 11.5 | 7.1 | 20.2 |
| Panama | 43.6 | 10.9 | 15.2 | 6.6 | 5.2 | 2.4 | 2.4 | 5.2 | 0.5 | 1.9 |
| Philippines | 70.7 | 49.5 | 66.2 | 37.9 | 21.2 | 10.1 | 7.1 | 21.7 | 16.7 | 15.7 |
| Romania | 42.1 | 31.8 | 33.5 | 20.5 | 5.2 | 3.3 | 2.0 | 14.3 | 10.2 | 3.5 |
| Serbia | 36.2 | 18.3 | 27.3 | 10.5 | 7.8 | 5.3 | 2.6 | 14.8 | 10.3 | 5.7 |
| South Africa | 44.0 | 17.9 | 41.8 | 11.6 | 6.9 | 3.1 | 2.3 | 12.9 | 16.7 | 8.4 |
| Tanzania | 61.9 | 32.1 | 66.7 | 27.4 | 16.7 | 7.1 | 11.9 | 16.7 | 9.5 | 20.2 |
| Turkey | 32.6 | 29.1 | 33.9 | 18.0 | 5.2 | 3.7 | 2.8 | 19.7 | 9.4 | 6.9 |
| Uganda | 60.9 | 24.8 | 49.0 | 23.0 | 12.2 | 3.2 | 5.0 | 16.4 | 8.3 | 11.3 |
| Ukraine | 28.6 | 22.4 | 21.9 | 11.0 | 4.7 | 1.9 | 4.6 | 14.7 | 9.1 | 4.0 |

*Source: UNESCO Institute of Statistics (2015a)*

**Table 5: Business enterprises that cooperated with other actors of the NIS (as a percentage of innovation-active firms)**

| Country | Internal | Market | | | | Other | |
|---|---|---|---|---|---|---|---|
| | Other enterprises within the group | Suppliers of equip-ment | Clients or customers | Competitors | Consultants | Universities | Government research institutes |
| Argentina | - | 12.9 | 7.6 | 3.5 | 9.3 | 14.5 | 16.1 |
| Brazil | - | 10.0 | 12.8 | 5.2 | 6.2 | 6.3 | - |
| Bulgaria | 3.9 | 13.6 | 11.2 | 6.4 | 5.8 | 5.7 | 3.0 |
| Colombia | - | 29.4 | 21.0 | 4.1 | 15.5 | 11.2 | 5.3 |
| Costa Rica | - | 63.9 | 61.1 | 16.5 | 49.6 | 35.3 | 8.1 |
| Cuba | - | 15.3 | 28.5 | 22.1 | - | 14.9 | 26.4 |
| Ecuador | - | 62.4 | 70.2 | 24.1 | 22.1 | 5.7 | 3.0 |
| Egypt | - | 3.6 | 7.1 | 0.9 | 7.1 | 1.8 | 0.9 |
| El Salvador | - | 36.9 | 42.1 | 1.3 | 15.3 | 5.5 | 3.4 |
| Ghana | 28.1 | 21.1 | 31.6 | 17.5 | 22.8 | 12.3 | 8.8 |
| Hungary | 15.5 | 26.9 | 21.1 | 16.4 | 20.1 | 23.1 | 9.9 |
| Indonesia | - | 25.7 | 15.9 | 8.0 | 10.2 | 8.4 | 4.9 |
| Kenya | - | 53.8 | 68.8 | 54.8 | 51.6 | 46.2 | 40.9 |
| Malaysia | - | 32.9 | 28.8 | 21.2 | 25.5 | 20.7 | 17.4 |
| Mexico | - | - | - | 9.7 | - | 7.0 | 6.1 |
| Morocco | - | 25.6 | - | - | 19.2 | 3.8 | - |
| Panama | - | 64.5 | 0.5 | 18.5 | 3.8 | 1.4 | 7.6 |
| Philippines | 91.2 | 92.6 | 94.1 | 67.6 | 64.7 | 47.1 | 50.0 |
| Romania | 2.8 | 11.7 | 10.6 | 6.2 | 5.9 | 7.2 | 3.1 |
| Serbia | 16.6 | 19.4 | 18.3 | 13.0 | 12.4 | 12.5 | 9.8 |
| South Africa | 14.2 | 30.3 | 31.8 | 18.6 | 21.1 | 16.2 | 16.2 |
| Ukraine | - | 16.5 | 11.5 | 5.3 | 5.7 | 4.2 | 6.6 |

*Source: UNESCO Institute of Statistics (2015a)*

**Major findings from innovation surveys about innovative activity at the core**

What have we learned from these surveys done across the world? Based on the summary results reported in Tables 2-5, the following inferences could be drawn:

- There is remarkable statistical regularity in the results across developed and developing economies.
- Number of innovating firms has been on the increase; this could be a problem of self-selection.
- Acquisition of capital goods for introducing innovations is the most important item of expenditure.
- Intramural R&D forms not more than one-third of innovation expenditures.

- Much of the innovation expenditures are self-financed; dependence on governmental support schemes is not high.
- Suppliers and users are the main source of information on innovation and not universities or research institutes. This is a major finding, as much effort is made to improve the interactions between research institutes/universities and business enterprises. As suppliers and clients or customers are market sources, this could be an indication of the importance of the connection to the market for the innovation process.
- As far as the factors that hamper innovation are concerned, cost factors and, in particular, lack of funds within the business enterprise or enterprise group were the main barriers faced by the innovation-active business enterprises. However, what is surprising is that despite the fact that enterprises cite cost factor as the main barrier, dependence on governmental support schemes is not high.

### Box 1: Innovation surveys

There is a general feeling that measuring innovation through R&D expenditure and patents granted does not adequately measure innovative activity that goes on in manufacturing and service enterprises. This is because in most countries of the world, and especially in developing countries, the industrial structure is positively skewed with a large number of Small and Medium Enterprises (SME) and a small number of large enterprises. Most of the SMEs do not have adequate financial and human resources to perform R&D and take out patents. Yet, not only some of these enterprises do innovate, but also studies done across the world have shown that SMEs are actually more innovative than large enterprises. Hence, relying on conventional measures such as R&D expenditure and patents underestimates the amount of innovations done by the SME sector. In order to overcome this limitation, innovation surveys have been conducted, first by the European Union starting with the 1993 survey. This idea has now spread to more than 60 countries of the world (see UNESCO Institute of Statistics 2015a for a summary of the results from across the world). The surveys are conducted by employing the so-called Oslo Manual. The manual has undergone three editions, 1992, 1996 and 2005. The innovation surveys, through a sample of manufacturing and service sector enterprises, collect data on six different aspects of innovative activity. The six different aspects are:

- Identifying an innovator;
- Innovation activities and expenditures;
- Sources of information on innovation;
- Effects of innovation;
- Factors hampering innovation; and
- Organisational and marketing innovation.

Each survey collects data on three different years although quantitative data are reported only for the latest year of the three-year period covered. The data collected by innovation surveys have the following characteristics:

- Most of the data from the innovation surveys are qualitative, i.e. discrete: dichotomous (binary), ordered categorical (such as the importance of obstacles on a five-point Likert scale) or unordered categorical (e.g. different sources of information for innovation).
- A number of variables are censored (i.e. collected only for a subset of the firms in the overall sample). Those are, for instance, the variables related to innovation expenditures and innovation output. In a number of cases, the value for the censored variable can safely be put equal to zero,

such as the share of sales due to new products. In other cases, however, it has no meaning when censored, e.g. the nature of partners for non-cooperating firms. The censoring should be corrected for to avoid potential selection biases.

- Many of the variables, qualitative and quantitative as well, are of a subjective nature, being largely based on the personal appreciation and judgment of the respondents. One of the most interesting variables and that is relatively well known, the share in total sales due to new products, has, for example, values that tend to be rounded (10%, 15%, 20%,), attesting to its subjective nature and suggesting that perhaps we should treat it as a categorical variable and not make too much out of its continuous variations.
- Basically innovation survey data are of a cross sectional nature, and it is always problematical to address econometric endogeneity issues and make statements about directions of causality with cross-sectional data. Many of the variables in the innovation surveys concern strategic decisions of the enterprise: doing R&D and innovating, applying for financial support and intellectual property protection, cooperating in innovation. These decisions are largely determined simultaneously and are jointly dependent on third factors, which we do not know or do not observe and for which we have very few exogenous or environmental variables that can serve as relevant and valid instruments.

The results of the innovation surveys thus give us a better picture of the nature and quantity of innovations done in a nation state.

Note: For a sample questionnaire for conducting a typical innovation survey, see Annex 2.

*Source: Own compilation, Mairesse and Mohnen (2010)*

**Four critical issues to be borne in mind while interpreting the data from innovation surveys**

While innovation survey data do allow us to have a better picture of innovative activity, the following points will have to be borne in mind:

- The definition of the term innovation can lead to a number of measurement errors. This is because it is interpreted as a new product or process implemented that is new to the firm even if it is not new to the universe in which the firm is located. Given the subjective nature of the definition, it can lead to different enterprises interpreting the term in a different manner. Moreover, the enterprises self-select themselves as to an innovator or not. This can, in turn, lead to a biased reporting of the number of innovating firms. For instance, according to Table 2, over 50 per cent of the business enterprises in Costa Rica, Nigeria and Tanzania have introduced product innovation during the reference period.
- Most of the countries have reported low response rates to innovation surveys. Response rates are always defined with respect to the sample as Response Rate = (Realised Sample of Business Enterprises ÷ Actual Sample of Business Enterprises × 100). So a low response rate limits the generality of the results obtained.
- One of the most important parts of the innovation survey is the part dealing with innovation activities and expenditures as this part picks up the non-R&D routes to innovation. However, since firms do not maintain proper quantitative data on these items of expenditure, there is a tendency on the part of the person filling in this part of the questionnaire to

guess and fill in with some estimated data. Many countries have also reported missing values to this question. This further limits the accuracy of the relative share of these different non R&D expenditure items.

- Hitherto, very few countries that did innovation surveys have actually used the results for designing policy instruments that can impact on innovations. For instance, although innovation survey data from across the world have pointed to the importance of acquisition of capital goods as an important innovation generating activity, hardly any country has policy instruments that are designed to enable business enterprises acquire new vintages of capital goods and equipment. Innovation policy in most countries of the world is R&D policy only. In fact, as noted by UNESCO Institute of Statistics (2015a), "contrary to research and experimental development (R&D) indicators, a flagship innovation indicator has not been established yet, despite the existence of methodological guidelines for more than 20 years".

## Step 3: Diagnosing the Health of the NIS by Employing Innovation Indicators

An important step in implementing the NIS framework is to measure its health at regular intervals, say once in two years. Some developed countries do this very systematically by employing a set of innovation indicators. For instance, the National Science Board of the United States does every two years a detailed analysis of the S&T health of that country by publishing a flagship document called the *Science and Engineering Indicators*. The UNESCO brings out a *UNESCO Science Report*, once every five years measuring the S&T health of a large number of developed and developing countries, the latest 2015 report covers 189 countries, while 11 countries are covered in detail. The OECD publishes every year a document called the *Main S&T Indicators* measuring the S&T health of the OECD member countries plus even non-OECD countries such as Argentina, the People's Republic of China, Taiwan Province of China, Romania, Russia, South Africa and Singapore. Further, a Science, Technology and Industry Scoreboard is brought out every two years. The World Bank publishes every year a set of innovation indicators under its publication, the *World Development Indicators*, the issue of 2014 covers 214 economies. The Japan Science and Technology Agency (JSTA) has published in 2015 a document titled the *Current Status of S&T in ASEAN Countries,* covering all the ASEAN countries (this is not a regular publication). Apart from these data on specific innovation indicators such as patents is brought out by World Intellectual Property Organization (WIPO), and the data for computing technology trade balances of countries are contained in the comprehensive database, the United Nations Service Trade Statistics Database.

Together, all these publications cover a large number of indicators. They are broadly defined as input and output indicators. The input indicators are: (1) R&D expenditure; (2) the density of scientists and engineers; and (3) venture capital investments. The output indicators are (1) patents; (2) high technology manufactured exports; and (3) technology trade balance. We now discuss each of these six indicators in some detail. Of these six, R&D expenditure and patent data are the most widely used set of indicators to measure the health of an NIS. This is because both are readily available and are collected using a harmonized set of guidelines. This makes comparisons, both across countries and sectors within countries, eminently possible. We will first discuss the R&D expenditure data followed by patents, and also contrast the two and discuss sources of data on these and issues of interpretation.

**R&D expenditure**

This is the most universally used indicator of innovative activity at the level of a country, a sector within a country, an industry within a sector, or a firm within an industry. Most countries collect data on R&D expenditure by all the constituents of the NIS. Data are collected according to the guidelines provided in the key OECD document for the collection of R&D statistics, titled the *Standard Practice for Surveys of Research and Experimental Development*, popularly known as the *Frascati Manual*. The manual defines R&D as comprising both the production of new knowledge and new practical application of knowledge. R&D is conceived as covering three different kinds of activities: basic research, applied research and experimental development, and these are distinguished in terms of their distance from application. R&D data are often classified according to multiple criteria: type of R&D, sector of performance, sources of finance, socio-economic objectives and fields of research. There are two major components of R&D data. The first one is capital, which includes land, buildings and equipment that are used in the R&D laboratory. The second one is the recurring or revenue expenditure, which is primarily composed of the salaries of scientists and engineers. As a rule of thumb, for any nation and for a given year, the capital expenditure accounts for about a third of total R&D expenditure for that nation and that year while the remaining two-thirds is accounted for by recurring expenditure. If this is empirically correct, the most important issue in raising R&D expenditure is the contribution of scientists and engineers. This means that for R&D to result in new products and processes, the country requires good quality scientists and engineers. Buildings and equipment are not constructed and acquired every year, but once in a while only. The crucial role played by scientists and engineers is very often lost sight of in discussions on R&D investments.

**Inter-temporal and inter-spatial comparison of R&D**

Once the R&D data are acquired, there are two types of comparisons that one can make. First, over time in a specific NIS over a period of time (temporal comparison) and the second is comparing one NIS over another (spatial comparison). While performing inter-temporal comparison, one has to correct for price inflation. This is accomplished by dividing the R&D expenditure at current prices or nominal prices with an appropriate deflator such as the implicit Gross Domestic Product (GDP) deflator. One can then get the real R&D expenditure, and movements in it will give a more accurate picture of the increase or decrease in innovative activity.

$$\text{Real R\&D expenditure} = \frac{\text{Nominal R\&D Expenditure} \times 100}{\text{Deflator (= implicit GDP deflator)}}$$

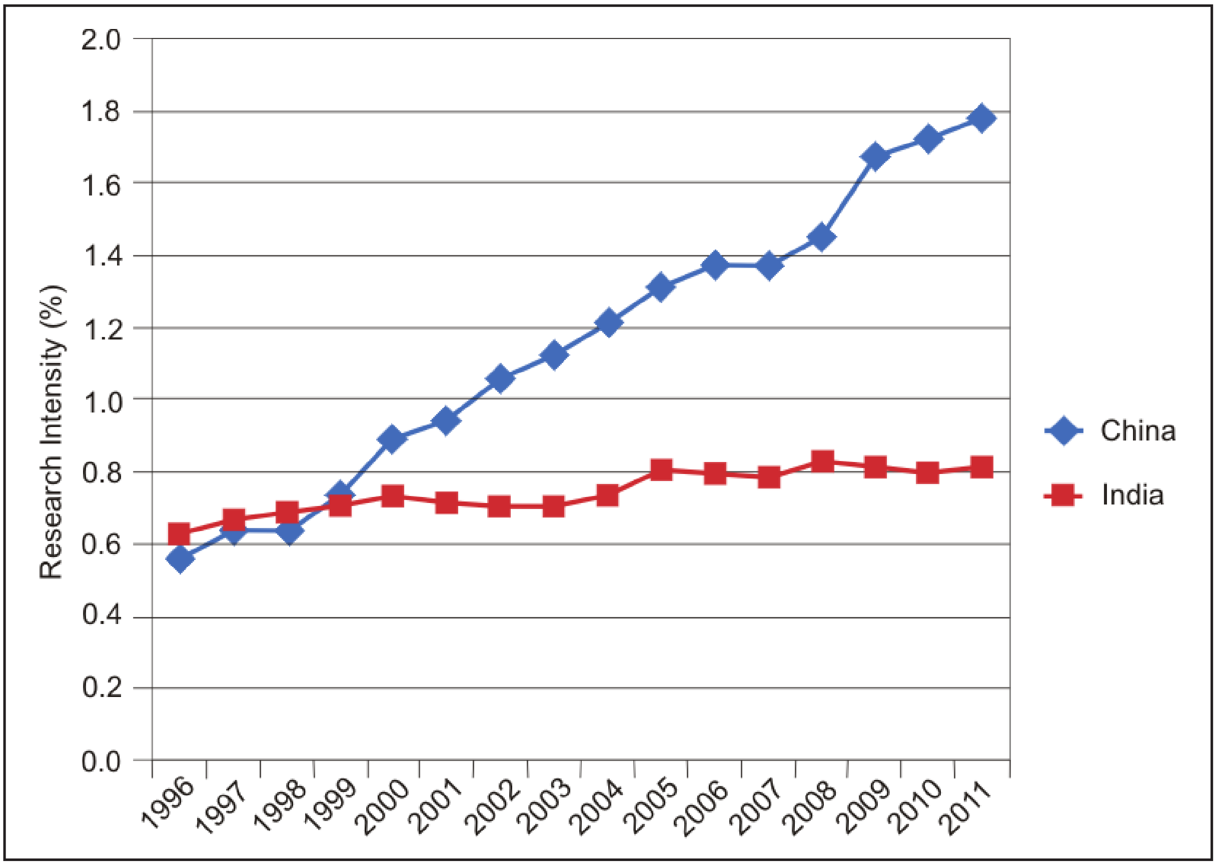
For inter-spatial comparisons, what is usually done is to convert the R&D expenditure of a nation valued in its local currency to a common numeraire such as the US dollar by using the market exchange rate between the local currency and US dollar. However, this simple conversion can bias the results as the purchasing power of US dollar, or for that matter any foreign currency, is not uniform across countries. Therefore, the R&D expenditure of two countries in a specific year needs to be converted to purchasing power parity in US dollar (PPP$) and then compared. Another issue to be borne in mind while making inter-spatial comparisons is that R&D expenditure, which in this case is GERD, must be converted to an intensity figure by dividing it with the GDP of the respective country. In short, while making inter-spatial comparisons, the following two steps have to be necessarily gone through:

Step 1 : Convert GERD in national currency to GERD in PPP$

Step 2 : Convert the absolute value of GERD in PPP$ to an intensity figure by dividing it with the GDP of that country, or (GERD PPP$ ÷ GDP) × 100

Figure 3 gives a comparison of the research intensity of the People's Republic of China and India, as determined through the steps cited above. It is seen that the People's Republic of China, where much of the R&D is done by business enterprises, is more innovative as it has a GERD-to-GDP ratio increasing and almost touching 2 per cent, whereas in India it is more or less stagnant. It is also interesting to note that, even in India, while the share of business enterprises in the performance of R&D has increased, almost two-thirds of the country's GERD is still accounted for by the government. India's GERD-to-GDP ratio is likely to increase when more and more R&D is performed by business enterprises.

**Figure 3: Comparison of GERD to GDP ratio of the People's Republic of China and India**




*Source: UNESCO Institute of Statistics*

The main limitation of R&D is that it is an input measure. Business enterprises may invest in R&D, but it may not result in new products or processes. This leads us to a very universally used output indicator of innovation – number of patents.

**Patents**

A patent is a legal document that grants monopoly rights over a specific innovation for a specified period of time (~20 years). Why? To provide incentives to innovate: if inventions could be copied, nobody will incur the fixed costs of developing it. The United States consider patents important enough to be enshrine a patent law in the country's Constitution. Recent changes in international governance rules with respect to innovations and patents were among the most hotly debated issues under the agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS). Patents involve a deal: monopoly rights in exchange for disclosure, which further promotes innovation. As R&D and innovation become more important in the developing world, patent protection will gain in stature.

***Types of patents***

There are essentially two types of patents: utility patents for new inventions and design patents for ornamental changes. In general terms, a "utility patent" protects the way an article is used and works, while a "design patent" protects the way an article looks. The ornamental appearance of an article includes its shape/configuration or surface ornamentation or both. Both design and utility patents may be obtained on an article if invention resides both in its utility and ornamental appearance. While utility and design patents afford legally separate protection, the utility and ornamentation of an article may not be easily separable. Articles of manufacture may possess both functional and ornamental characteristics.

Some of the more common differences between design and utility patents are summarized below:

(a) The term of a utility patent on an application filed on or after 8 June 1995 is 20 years, measured from the filing date in the United States, while the term of a design patent is 14 years measured from the granting date.

(b) Maintenance fee is required for utility patents, while no such fee is needed for design patents.

(c) Design patent applications entail a single claim, while utility patent applications can have multiple claims.

Table 6 presents the distribution of utility vs. design patents granted to all Asian countries at the USPTO in 2014.

***Utility models or petit patents***

As noted before, most of the firms in developing countries are of the SME type. SMEs innovate incrementally. These innovations may not satisfy the criteria of novelty, inventiveness and industrial application in the same degree as an invention that can qualify for a patent. Other than less stringent patentability requirements, utility models also has a shorter patent term of 6 to 15 years, as against patents that now has a term of 20 years from the date of application. The number of utility models an SME has is a good indicator of its potential. Many Asian countries have utility models in their intellectual property rights (IPR) regime. India is a notable exception to this, although there is now an active discussion on including it in the country's IPR regime.

**Table 6: Relative share of utility and design patents in the total USPTO patents, 2014**

| Country | Utility (No.) | Design (No.) | Total (No.) | Share of utility (%) | Share of design (%) |
|---|---|---|---|---|---|
| People's Republic of China | 7,236 | 676 | 7912 | 91.46 | 8.54 |
| India | 2,987 | 57 | 3044 | 98.13 | 1.87 |
| Republic of Korea | 16,469 | 1,630 | 18,099 | 90.99 | 9.01 |
| Malaysia | 259 | 12 | 271 | 95.57 | 4.43 |
| Pakistan | 10 | 0 | 10 | 100 | 0 |
| Philippines | 44 | 1 | 45 | 97.78 | 2.22 |
| Singapore | 946 | 60 | 1,006 | 94.04 | 5.96 |
| Sri Lanka | 4 | 1 | 5 | 80 | 20 |
| Taiwan Province of China | 11,332 | 908 | 12,240 | 92.58 | 7.42 |
| Thailand | 75 | 24 | 99 | 75.76 | 24.24 |
| Viet Nam | 6 | 1 | 7 | 85.71 | 14.29 |

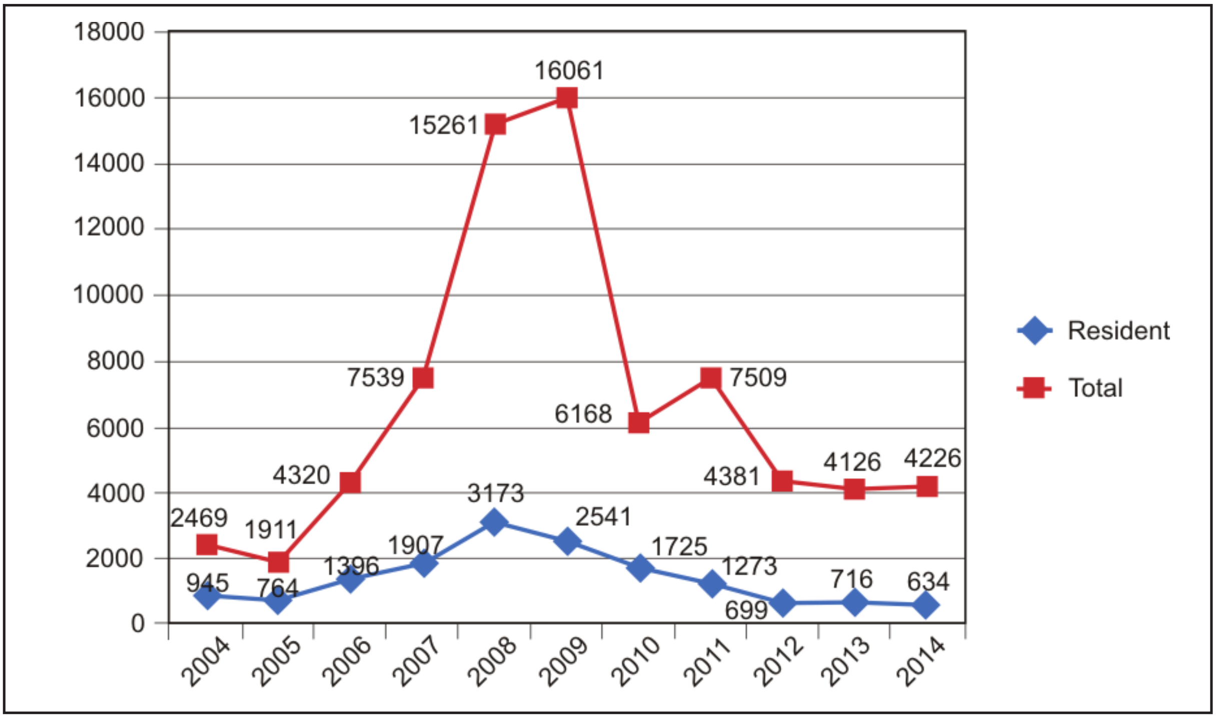
*Source: Computed from USPTO*

***Types of patent data***

**(1) Domestic patents:** These are patents granted to the residents of a country by the patent office of that country, such as the number of patents issued to Indian residents by the India patent office (Figure 4). The data actually show that the number of patents granted to residents has come down in both absolute and relative terms. Whereas residents were accounting for about 38 per cent of total patents 2004, it has significantly come down to about 15 per cent of the total in 2014.

**(2) Foreign patents:** These are patents issued by a foreign patent office, such as USPTO or the European Patent Office (EPO). A foreign patent granted is a better indicator for making inter-spatial comparisons, as the different patent offices may interpret differently the three criteria for patenting – novelty, inventiveness and industrial application. This subjectivity may lead to patent being granted for an invention in one jurisdiction, but the same invention being denied a patent in another jurisdiction. Therefore, the practice in the innovation studies literature is to use the number of patents granted at the USPTO as a measure of innovation of that country. USPTO is preferred because of two specific reasons: (1) USPTO shows the least home country advantage bias as more than 50 per cent of the patents issued at the USPTO have gone to non-US residents (Figure 5); and (2) the United States is considered to be the major market for disembodied technologies. Thus, if a business enterprise wants to signal to the rest of the world its technological capability, USPTO is the natural choice. Since it costs money (application fee plus maintenance fee) to file patents at USPTO, business enterprises, institutions and individuals usually self-select and invest in only their best inventions at USPTO. In short, for these reasons, the number of USPTO patents granted (Table 7) to a country is a good indicator of its innovation performance.

**Figure 4: Trends in the total number of patents and those granted to domestic residents by Indian patent office during 2004 through 2014**

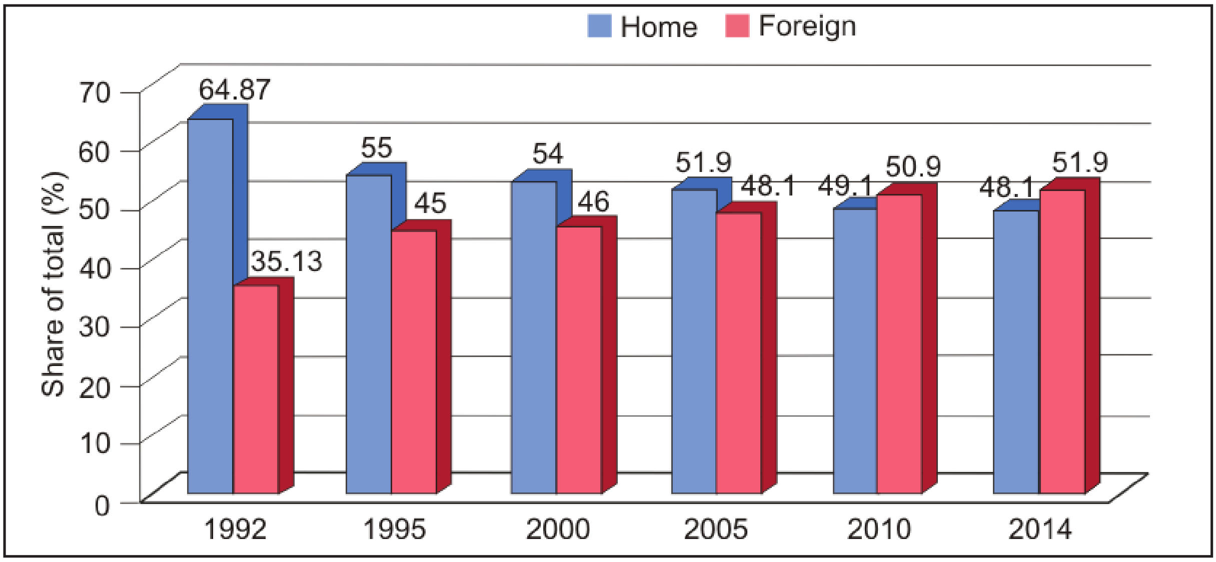



*Source: Controller General of Patents, Designs, Trademarks, and Geographical Indication (2014)*

An interesting aspect shown by Table 7 is the fact that the Republic of Korea and Taiwan Province of China are securing patents annually, which is more than the annual patents granted to developed European countries such as Germany, France or the United Kingdom. Furthermore, the People's Republic of China and India also have increased their innovative activity during this period, as have almost all Asian countries. However, before drawing conclusions about the innovative performance of a country by just tracing the trends in foreign patent counts, one should also be finding out the assignee of these patents, as the assignee is actually the owner of the patent. Assignees are usually business enterprises (both domestic companies and MNCs).

Consider the USPTO patent document given in Figure 6. USPTO assigns a patent to a country on the basis of the country of citizenship of the first-named inventor. In this case, all the inventors are United Statescitizens and working for a United States company. The company – Interdynamics Inc. is actually the assignee or the owner of the patent. It is possible for an MNC to set up its R&D facility in a foreign location, such as India, and then take out patents at the USPTO based on research done

**Figure 5: Home country advantage bias is low and decreasing over time at USPTO**




*Source: Based on USPTO data available at http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports_stco.htm (accessed on 24 November 2015)*

in India. USPTO will term these patents as Indian patents although its actual ownership or assignee is an MNC. Therefore, an increase in the patent count emanating from India may not be because of India becoming more innovative. Rather, the correct interpretation should be that India is becoming an important location for innovative activity. Table 8 illustrates this point. It is seen that of the top ten assignees of patents from the People's Republic of China are largely domestic corporations, universities or individuals, with only two MNCs. On the contrary, in India, eight out of the top ten assignees are MNCs. In short, although the number of patents granted to both the People's Republic of China and India shows a sharp increase during the last 15 years or so, the interpretation of this increase in terms of a country's innovative performance is different.

**Figure 6: Front page (partial) of a USPTO patent document**

**United States Patent 6,539,988**

Pressurized container adapter for charging automotive systems

Inventors:
**Cowan; David M.** (Brooklyn, NY); **Schapers; Jochen** (New York, NY); **Trachtenberg; Saul** (New York, NY); **Nikolayev V.** (Flushing, NY)

Assignee: **Interdynamics, Inc. . (Brooklyn, NY)**

Filed: **December 28, 2001**

**Current U.S. Class: 141/67;** 137/614.04; 141/351; 251/149.1

**Intern'l Class:** B65B

*Primary Examiner:* Douglas; Steven O.

*Attorney, Agent or Firm:* Livesohn, Lerner, Berger & Langsam LLP

*Source: Trajtenberg (2005), http://www.tau.ac.il/~manuel/R&D_course/ (accessed on 26 November 2015)*

**Table 7: Trends in the number of utility patents granted at the USPTO to inventors from various Asian and European countries, 2001-2014**

| Country | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Japan | 33223 | 34858 | 35515 | 35348 | 30341 | 36807 | 33354 | 33682 | 35501 | 44813 | 46139 | 50677 | 51919 | 53849 |
| Germany | 11260 | 11280 | 11444 | 10779 | 9011 | 10005 | 9051 | 8914 | 9000 | 12363 | 11919 | 13835 | 15498 | 16550 |
| United Kingdom | 3955 | 3829 | 3619 | 3441 | 3141 | 3579 | 3291 | 3085 | 3173 | 4299 | 4292 | 5211 | 5806 | 6487 |
| France | 4041 | 4035 | 3868 | 3380 | 2866 | 3431 | 3130 | 3163 | 3140 | 4450 | 4532 | 5386 | 6083 | 6691 |
| Republic of Korea | 3538 | 3786 | 3944 | 4428 | 4352 | 5908 | 6295 | 7548 | 8762 | 11671 | 12262 | 13233 | 14548 | 16469 |
| Taiwan Province of China | 5371 | 5431 | 5298 | 5938 | 5118 | 6361 | 6128 | 6339 | 6642 | 8239 | 8781 | 10646 | 11071 | 11332 |
| Canada | 3606 | 3431 | 3427 | 3374 | 2894 | 3572 | 3318 | 3393 | 3655 | 4852 | 5014 | 5775 | 6547 | 7043 |
| Switzwerland | 1420 | 1364 | 1308 | 1277 | 995 | 1201 | 1035 | 1112 | 1208 | 1608 | 1663 | 1831 | 2270 | 2398 |
| Italy | 1709 | 1751 | 1722 | 1584 | 1296 | 1480 | 1302 | 1357 | 1346 | 1798 | 1885 | 2120 | 2499 | 2628 |
| Sweden | 1741 | 1675 | 1521 | 1290 | 1123 | 1243 | 1061 | 1060 | 1014 | 1434 | 1710 | 2081 | 2271 | 2767 |
| Netherlands | 1332 | 1391 | 1325 | 1273 | 993 | 1323 | 1250 | 1330 | 1288 | 1615 | 1742 | 1904 | 2252 | 2505 |
| Israel | 970 | 1040 | 1193 | 1028 | 924 | 1218 | 1107 | 1166 | 1404 | 1819 | 1981 | 2474 | 3012 | 3471 |
| People's Republic of China | 195 | 289 | 297 | 403 | 402 | 661 | 772 | 1225 | 1655 | 2657 | 3174 | 4637 | 5928 | 7236 |
| Australia | 876 | 859 | 902 | 953 | 910 | 1325 | 1265 | 1291 | 1221 | 1748 | 1921 | 1525 | 1631 | 1693 |
| Belgium | 718 | 722 | 622 | 612 | 519 | 625 | 520 | 510 | 594 | 820 | 802 | 866 | 1062 | 1220 |
| Finland | 732 | 809 | 865 | 918 | 720 | 950 | 850 | 824 | 864 | 1143 | 951 | 1064 | 1221 | 1338 |
| Austria | 589 | 530 | 592 | 540 | 463 | 577 | 457 | 464 | 503 | 727 | 753 | 858 | 1009 | 1180 |
| Denmark | 479 | 426 | 529 | 414 | 358 | 439 | 388 | 391 | 390 | 605 | 730 | 850 | 921 | 1051 |
| India | 178 | 249 | 342 | 363 | 384 | 481 | 546 | 634 | 679 | 1098 | 1234 | 1691 | 2424 | 2987 |
| Singapore | 296 | 410 | 427 | 449 | 346 | 412 | 393 | 399 | 436 | 603 | 647 | 810 | 797 | 946 |
| Hong Kong, China | 237 | 233 | 276 | 312 | 283 | 308 | 338 | 311 | 305 | 429 | 419 | 532 | 540 | 606 |
| South Africa | 120 | 113 | 112 | 100 | 87 | 109 | 82 | 91 | 93 | 116 | 123 | 142 | 161 | 152 |
| Malaysia | 39 | 55 | 50 | 80 | 88 | 113 | 158 | 152 | 158 | 202 | 161 | 210 | 214 | 259 |
| Thailand | 24 | 44 | 25 | 18 | 16 | 31 | 11 | 22 | 23 | 46 | 53 | 36 | 77 | 75 |
| Philippines | 12 | 14 | 22 | 21 | 18 | 35 | 20 | 16 | 23 | 37 | 27 | 40 | 27 | 44 |
| Viet Nam | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 5 | 6 |
| Indonesia | 4 | 7 | 9 | 4 | 10 | 3 | 5 | 5 | 3 | 6 | 7 | 8 | 15 | 9 |
| Islamic Republic of Iran | 2 | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 6 | 7 | 16 | 25 | 35 | 28 |
| Pakistan | 2 | 1 | 0 | 2 | 3 | 2 | 1 | 3 | 3 | 2 | 4 | 13 | 12 | 10 |
| Bangladesh | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 3 | 2 |

*Source: Compiled from USPTO, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_utl.htm (accessed on 25 November 2015)*

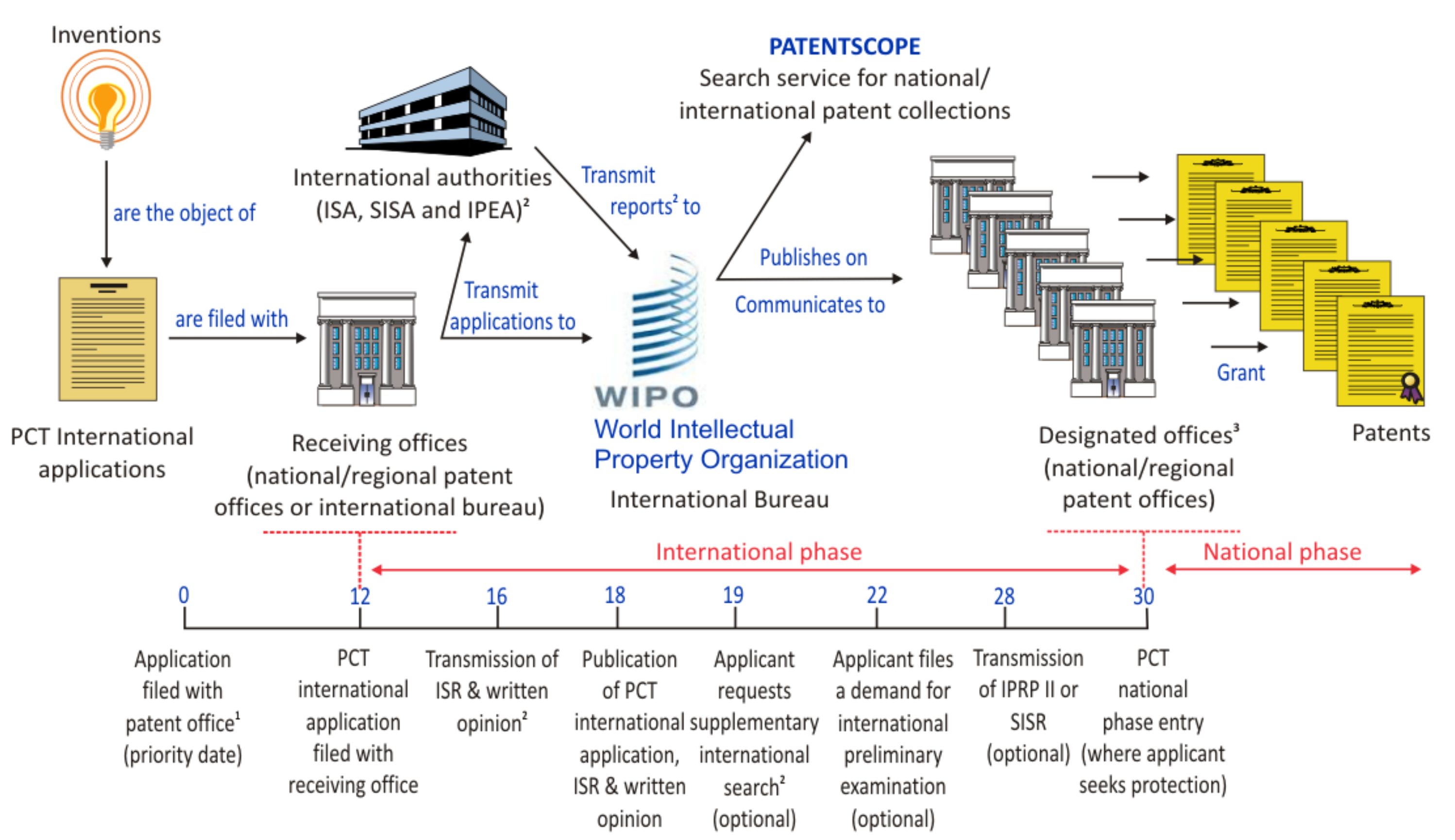
**Table 8: First named assignee in the top 10 patentees from the People's Republic of China and India at the USPTO (2010-2014)**

| First-named Assignee | 2010 | 2011 | 2012 | 2013 | 2014 | Total |
|---|---|---|---|---|---|---|
| **China** | | | | | | |
| Huawei Technologies Co. Ltd. | 245 | 352 | 503 | 621 | 690 | 2411 |
| Hong Fu Jin Precision Industry (Shenzshen) Co. Ltd. | 308 | 374 | 599 | 700 | 351 | 2332 |
| Individually owned patent | 206 | 193 | 295 | 281 | 325 | 1300 |
| ZTE Corporation | 22 | 33 | 99 | 269 | 701 | 1124 |
| Tsinghua Univesity | 101 | 100 | 147 | 189 | 230 | 767 |
| Microsoft Corporation | 160 | 133 | 169 | 143 | 125 | 730 |
| Hon Hai Precision Ind. Co. Ltd. | 207 | 168 | 99 | 70 | 62 | 606 |
| Shenzhen Futaihong Precision Ind. Co. Ltd. | 69 | 107 | 203 | 149 | 77 | 605 |
| Shenzhen China Star Optoelec-tronics Technology Co. Ltd. | 0 | 0 | 3 | 102 | 431 | 536 |
| International Business Machines Corporation | 26 | 64 | 106 | 158 | 139 | 493 |
| **India** | | | | | | |
| International Business Machines Corporation | 86 | 114 | 135 | 239 | 318 | 892 |
| General Electric Company | 53 | 86 | 115 | 131 | 124 | 509 |
| Texas Instruments Inc. | 55 | 40 | 67 | 64 | 83 | 309 |
| Council of Scientific & Industrial Research | 67 | 28 | 39 | 54 | 78 | 266 |
| Individually owned patent | 41 | 31 | 52 | 68 | 74 | 266 |
| Honeywell International Inc. | 35 | 45 | 37 | 66 | 73 | 256 |
| Hewlett-Packard Development Company L.P. | 26 | 44 | 56 | 40 | 69 | 235 |
| Symantec Corporation | 5 | 13 | 33 | 82 | 89 | 222 |
| Oracle International Corp. | 13 | 27 | 34 | 49 | 61 | 184 |
| Microsoft Corporation | 22 | 33 | 36 | 40 | 48 | 179 |

*Source: Compiled from USPTO*

**(3) *PCT patent applications*:** A world patent does not exist. Instead, in 1970, countries got together and contracted a treaty called the Patent Cooperation Treaty (PCT). The WIPO-administered treaty, provides a unified procedure for filing patent applications to protect inventions in each of its contracting states. A patent application filed under the PCT is called an international application, or PCT application. At present, there are 148 countries that are contracting parties to the PCT. The PCT makes it possible to seek patent protection for an invention simultaneously in 148 countries by filing a single "international" patent application instead of filing several separate national or regional patent applications. The granting of patents is under the control of the national or regional patent offices in what is called the "national phase". An overview of the PCT system is provided in Figure 7.

**Figure 7: Overview of the PCT system**




[1] Generally, applicants first file a national or regional patent application with their patent office, and file a PCT application within 12 months from priority date.

[2] International searching authorities (ISA) transmit international search reports (ISRs) and written opinions; authorities specified for supplementary search (SISA) transmit supplementary international search reports (SISR), international preliminary examining authorities (IPEA) transmit international preliminary reports on patentability (IPRP II).

[3] Called elected offices fro applicants having files demand for international preliminary examination.

*Source: World Intellectual Property Organization (2015)*

**Table 9: PCT national phase entries, Asia, 2009 to 2013**

| Country | Year of national phase entry | | | | | Regional share 2013 (%) | Change from 2012 (%) |
|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2011 | 2012 | 2013 | | |
| Japan | 79,134 | 91,240 | 96,101 | 112,862 | 120,839 | 69.9 | 7.1 |
| Republic of Korea | 12,606 | 13,565 | 14,213 | 17,238 | 19,086 | 11 | 10.7 |
| People's Republic of China | 5,145 | 7,724 | 12,913 | 16,978 | 18,106 | 10.5 | 6.6 |
| Israel | 4695 | 5,224 | 4,967 | 5,527 | 5,498 | 3.2 | -0.5 |
| India | 1891 | 2,570 | 2,950 | 3,322 | 3,890 | 2.2 | 17.1 |
| Singapore | 1,259 | 1,821 | 1,950 | 2,009 | 2,368 | 1.4 | 17.9 |
| Thailand | 30 | 51 | 72 | 120 | 686 | 0.4 | 471.7 |
| Turkey | 353 | 446 | 694 | 693 | 653 | 0.4 | -5.8 |
| Malaysia | 195 | 252 | 486 | 470 | 544 | 0.3 | 15.7 |
| Saudi Arabia | 189 | 207 | 241 | 211 | 381 | 0.2 | 80.6 |
| Others | 483 | 509 | 556 | 709 | 926 | 0.5 | 30.6 |
| Total | 105,980 | 123,609 | 135,043 | 160,139 | 172,977 | 30.6 | 8 |

*Source: Adapted from World Intellectual Property Organization (2015), p. 57*

***(4) Triadic patents:*** The methodology used for counting patents can influence the results, as simple counts of patents filed at a national patent office are affected by various kinds of limitations (such as weak international comparability) and highly heterogeneous patent values. To overcome these limits, and in order to improve the international comparability and quality of patent-based indicators, OECD has developed the concept of triadic patent families. Only patents registered in the same set of countries are included in the family: home advantage and influence of geographical location are therefore eliminated. Furthermore, patents included in the triadic family are typically of higher economic value: patentees only take on the additional costs and delays of extending the protection of their invention to other countries if they deem it worthwhile. A patent family is defined as a set of patents registered in various countries (i.e. patent offices) to protect the same invention. Triadic patent families are a set of patents filed at three of these major patent offices: EPO, USPTO and the Japan Patent Office (JPO). Triadic patent family counts are attributed to the country of residence of the inventor and to the date when the patent was first registered. About 49,000 triadic patent families were filed in 2010 (Table 10), compared with around 45,000 registered in 2000. The United States accounts for 28.1 per cent of patent families, a lower share compared with the 30.5 per cent recorded in 2000. The share of triadic patent families originating from Europe has also tended to decrease, losing almost 1 percentage point between 2000 and 2010 (28.6 per cent in 2010).

The origin of patent families has shifted towards Asian countries. The most spectacular growth was observed in the case of the Republic of Korea, whose share of all triadic patent families increased from 1.6 per cent in 2000 to 4.4 per cent in 2010. Strong rises are also observed for the People's Republic of China and India, with an average growth in the number of triadic patents of more than 28 per cent and 15 per cent a year, respectively, between 2000 and 2010. When triadic patent families are expressed relative to the total population, Japan, Switzerland, Sweden and Germany were the four most inventive countries in 2010, with the highest values recorded in Japan (118) and Switzerland (109). Ratios for Austria, Denmark, Finland, Israel, the Republic of Korea, the Netherlands and the United States are also above the OECD average (39). Conversely, the People's Republic of China has less than 0.7 patent families per million population.

The main problem with triadic family system data is that it is not available on a timely fashion. Furthermore, there is no easily access to information on the assignees of triadic patent family in a host economy. For these reasons, it is yet to emerge as an important indicator of inventive activity especially in developing countries.

***Patent as a measure of technological capability – the three conditions***

Lee (2013) proposes three conditions as a measure of technological capability by employing the patents data:

- Resident patenting catches up with the non-resident patenting in a host country;
- New invention patents (utility patents) catches up with utility models; and
- Business enterprise patenting catches up with individual inventor patenting.

A country satisfying these three conditions is said to be at the higher end of the technological capability ladder. Japan, the Republic of Korea and Taiwan Province of China are three Asian countries that satisfy these three conditions. The People's Republic of China too is rapidly moving towards satisfying these conditions.

***Drawing insights from patent data analysis***

(a) **Knowledge spillovers:** Analysis of patent data can provide us with valuable insights about a number of technological dimensions.  One of them is knowledge spillovers that occur in a specific geographical region or area. Innovation has a direct effect on welfare via different mechanisms like new products, quality improvements, productivity growth, lower prices, etc., and in principle these direct effects can be measured. Other than these direct effects, innovative activity also influences innovative endeavours of others or what may be termed as externalities. These non-pecuniary externalities, or knowledge spillovers in the widest sense, are difficult to be measured. Knowledge spillovers are one major factor favouring the emergence of industrial clusters or geographically concentrated industries. Jaffe, Trajtenberg and Henderson (1993) have argued that knowledge flows do leave a paper trail – in the form of patent citations, which can be used to track knowledge spillovers. For instance, if one patent is citing another patent, this link can be interpreted as a knowledge spillover (see Figure 8). Furthermore, patents provide information on the localization of the inventor. This would explain, for instance, why the Indian computer and information services industry is localized in Bangalore and the Indian pharmaceutical industry is localized in Hyderabad.

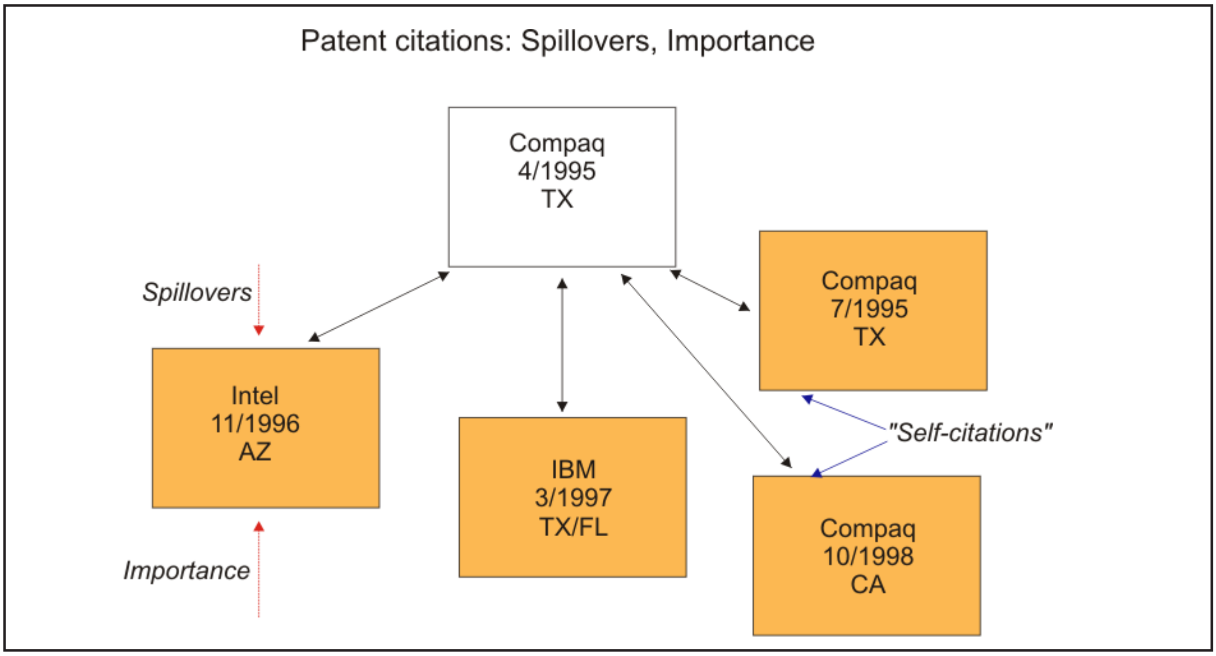
Two hypotheses that have come up for empirical testing in the literature are:

Hypothesis 1: If knowledge spillovers are localized within countries, then citations of patents generated within a country should come disproportionately from within that country;

Hypothesis 2: To the extent that regional localization of spillovers is important, citations should come disproportionately from the same state or metropolitan area as the original document.

Unfortunately, almost all the empirical research studies for verifying these two hypotheses are based on the developed country experience, that too of the United States. A second limitation is the fact that patent citations are known to be inserted by patent examiners and not by the primary inventors.

**Figure 8: Identifying knowledge spillovers from patent citations**




*Source: Trajtenberg (2005), http://www.tau.ac.il/~manuel/R&D_course/ (accessed on November 26, 2015)*

**Technology specialization of a country**

A convenient way of measuring the specialization of a country is through an index called the Patent Activity Index (National Science Board, 2016). A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index of greater/less than 1.0 indicates that a country is relatively more/less active in the technology area. Patents are classified by WIPO's classification of patents, which classifies International Patent Classification (IPC) codes under 35 technical fields. Table 11 maps out the technology specialization of three Asian counries, namely Japan, the Republic of Korea and Taiwan Province of China. It is seen that the three East Asian countries do specialise in semiconductor and host some of the leading MNCs in this field. So the technology specialisation pattern of the three is quite similar. Further, there is a focus on high technology areas in the three countries, and all the three have built up considerable technological capability to design, manufacture and sell state-of-the-art high technology products. Thus patent data can give us considerable insights into technological catch-up that countries undertake to keep pace with the world frontier.

**Table 10: Trends in triadic patent families in OECD and selected non-member countries (number)**

| Country | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Japan | 13,205 | 14,913 | 13,321 | 13,545 | 14,314 | 14,851 | 13,864 | 13,418 | 13,451 | 12,190 | 12,164 | 13,269 | 13,705 |
| Republic of Korea | 580 | 732 | 891 | 1,182 | 1,481 | 1,747 | 1,651 | 1,547 | 1,654 | 1,438 | 1,564 | 1,660 | 1 709 |
| United Kingdom | 1,652 | 1,633 | 1,469 | 1,507 | 1,519 | 1,512 | 1,520 | 1,501 | 1,434 | 1,398 | 1,390 | 1,374 | 1,371 |
| United States | 14,598 | 13,855 | 13,080 | 13,878 | 14,175 | 14,538 | 14,686 | 13,956 | 13,360 | 12,986 | 12,295 | 12,416 | 12,649 |
| EU 28 | 14,138 | 13,355 | 12,152 | 11,895 | 11,885 | 12,413 | 12,675 | 12,322 | 12,267 | 12,040 | 11,955 | 11,849 | 11,998 |
| OECD | 44,566 | 45,066 | 41,392 | 42,350 | 43,730 | 45,611 | 44,930 | 43,233 | 42,653 | 40,505 | 39,835 | 41,078 | 41,919 |
| Brazil | 27 | 29 | 46 | 33 | 28 | 31 | 29 | 31 | 35 | 35 | 34 | 35 | 36 |
| People's Republic of China | 59 | 71 | 100 | 157 | 202 | 219 | 299 | 311 | 393 | 429 | 630 | 768 | 958 |
| India | 38 | 54 | 82 | 128 | 110 | 106 | 121 | 111 | 119 | 133 | 154 | 171 | 183 |
| Indonesia | 1 | 4 | 2 | 3 | 2 | 1 | 1 | 4 | 1 | 2 | 2 | 2 | 2 |
| Russian Federation | 62 | 73 | 56 | 56 | 51 | 42 | 50 | 44 | 45 | 42 | 41 | 46 | 48 |
| South Africa | 28 | 36 | 16 | 15 | 33 | 20 | 25 | 25 | 23 | 26 | 22 | 22 | 21 |
| World | 45,006 | 45,570 | 41,949 | 43,036 | 44,419 | 46,326 | 45,781 | 44,098 | 43,675 | 41,571 | 41,119 | 42,552 | 43,590 |

*Source: OECD Patent Statistics, http://www.oecd-ilibrary.org/science-and-technology/data/oecd-patent-statistics_patent-data-en (accessed on 26 November 2015)*

**Table 11: Patent Activity Index of selected Asian countries (2012-14)**

| Japan | | Republic of Korea | | Taiwan, Province of China | |
|---|---|---|---|---|---|
| Technology | Activity index | Technology | Activity index | Technology | Activity index |
| Optics | 2.6 | Semiconductors | 2.6 | Semiconductors | 2.8 |
| Semiconductors | 1.5 | Optics | 1.7 | Basic comm. processes | 1.8 |
| Basic comm. processes | 1 | Digital communications | 1.6 | Optics | 1.6 |
| Measurement | 0.9 | Telecommunications | 1.5 | Control | 1.1 |
| Telecommunications | 0.9 | Basic comm. processes | 1.5 | Nanotechnology | 1.1 |
| Computer technology | 0.8 | Nanotechnology | 1.5 | Telecommunications | 0.9 |
| Nanotechnology | 0.8 | Computer technology | 0.9 | Computer technology | 0.9 |
| Control | 0.7 | Control | 0.6 | Measurement | 0.8 |
| Digital communications | 0.6 | Measurement | 0.5 | Digital communications | 0.5 |
| Biological materials | 0.6 | Biotechnology | 0.5 | Biological materials | 0.4 |
| Biotechnology | 0.5 | Biological materials | 0.4 | Pharmaceuticals | 0.4 |
| Medical technology | 0.4 | Pharmaceuticals | 0.3 | Biotechnology | 0.3 |
| Pharmaceuticals | 0.4 | Medical technology | 0.2 | Medical technology | 0.2 |
| IT management | 0.2 | IT management | 0.2 | IT management | 0.1 |

*Source: National Science Board (2016)*

### Advantages and Disadvantages of Patents as an Indicator of Innovation

Although patents have a fair amount of utility as a measure of innovation, one should also be aware of its advantages and disadvantages (Lee 2013).

#### *Advantages of patents*

- They are a direct outcome of the inventive process, and specifically of those that are expected to have a commercial impact. They are useful indicators to capture the proprietary and competitive dimensions of technological change.
- Since obtaining a patent is time-consuming and costly, inventors usually perform a self-selection of only those inventions that are likely to be useful.
- Patent data are disaggregated by technical field. This helps one understand the direction of technical change.
- Patent data are available for a large number of countries and for a long time series.

#### *Disadvantages of patents*

- Not all inventions are patented or patentable. The former may be due to strategic reasons.
- Different business enterprises have different propensity to patent.
- Strategic use of patents can reduce competition: patents may create barriers to entry and raise production costs of incumbent or new firms.
- Patents can hinder sequential innovation: patents held by one firm can increase costs of other firms' R&D, affecting the next generation of innovators (See Box 2).
- The patent system adversely affects smaller and start-up firms: both the points cited immediately above can create problems for smaller and start-up firms. Moreover, the high cost of monitoring, obtaining and defending patents create problems for such firms.

- Patent races are inefficient: competition to be the first to patent can lead to excessive and inefficient R&D spending.
- For developing countries in particular, strengthening and harmonizing patent rules through international agreements such as TRIPS have been controversial, especially increasing the prices of and access to life-saving drugs and agrochemicals. Furthermore, such agreements have erected barriers for developing country firms to enter many new and emerging technologies such a biotechnology.
- Finally, too much emphasis on patenting has increased the risk of patent litigation, which can reduce welfare, as the private rate of return for most innovations are far greater than the societal rate of return.
- Not all patents are developed into innovative products to solve practical challenges and generate value added.

## Box 2: Does patenting promote innovation?

"Take, first, the idea that patents give you a higher rate of innovation. If you look at things such as the number of inventions presented at international fairs, the evidence suggests that 19th-century countries that lacked patent systems were no less innovative than those, which had them, though they did innovate in somewhat different areas. Reviewing 23 20th Century studies Boldrin and Levine (2012) found "weak or no evidence that strengthening patent regimes increases innovation"—all it does is lead to more patents being filed, which is not the same thing. Several of these studies found that "reforms" aimed at strengthening patent regimes, such as one undertaken in Japan (http://www.nber.org/papers/w7066) in 1988, for the most part boosted neither innovation nor its supposed cause, R&D spending".

*Source: Economist magazine, August 8, 2015*

**TRIPS Compliance of National Patent Regimes**

A very important change that occurred in national patent regimes across the developing and developed world is their harmonisation through the TRIPS Agreement, which came into being on 1 January 1995, with developing countries granted a transition period of 10 years, i.e., until 1 January 2005 to apply the provisions to product patents (where such protection was absent as on 1 January 1995). But the transition period for the Least Developed Countries (LDCs) has been further extended in stages up to 1 July 2021 or when a particular country ceases to be in the least developed category, if that happens before 2021. TRIPS introduced minimum standards for protecting and enforcing IPR to an extent previously unseen at the global level. For some countries, in respect of medicines, TRIPS meant the introduction of patents and limited forms of regulatory data protection; for others it meant extending patent protection for pharmaceutical products for the first time; and for some others already granting patents, it meant extending the life of newly granted patents to 20 years from the date of application. TRIPS compliance was supposed to herald a number of positive and, of course, a few negative effects. One of the important positive benefits was that strengthening of the patent regime would result in increased licensing of disembodied technology from MNCs, as MNCs are no longer worried about copying and reverse engineering by local business enterprises.

However, available evidence from across the world shows that this has not happened; stronger IPR regimes have not precipitated increased flow of disembodied technology (Mani and Nelson 2013).

### Relative strengths and weaknesses of R&D expenditure vs. patents

The relative strengths and weaknesses of the two most frequently used innovation indicators are summarised in Table 12.

**Table 12: R&D expenditure vs. patents**

| Measure | Strengths | Weaknesses |
|---|---|---|
| Research & Development | • Regular data collection<br>• Sectoral uniformity across industries<br>• Internationally comparable | • Monetary adjustment required for international comparability<br>• Underestimates innovation in small firms<br>• Excludes design part of software and production engineering<br>• Considers only a small part of innovative activities in services |
| Patents | • Regular data collection<br>• Detailed breakdown for technological categories<br>• Internationally comparable<br>• Direct measure of technological output | • Not all inventions are patented<br>• Not all innovations are patentable<br>• Differences in the propensity to patent across sectors<br>• Considers only a small part of innovative activities in services |

**High technology manufactured exports:** The share of high technology exports in the total manufactured exports of a country is also an output indicator of its innovation performance. If that share is increasing over time, then we say that the country is becoming more and more innovative. First of all, we need to define the products that are termed as high technology. This would help us to derive the data on high technology export intensity of a country. The most commonly used definition of high technology is by Hatzichronoglou (1997), who prepared a list of high technology products corresponding to the three-digit Standard International Trade Classification (SITC) Revision 3. This definition appears to be better than the previous attempts because the products are immediately defined as high tech according to their SITC classification, thus obviating the need for any concordance tables. Table 13 lists these products. It must, however, be mentioned that such lists are not perfect: in very specific terms the above definition has the following three limitations:

- First, high-tech products cannot be selected by quantitative methods alone unless a relatively high level of aggregation is used. Resorting to expert opinion does yield very detailed lists, but the results can't readily be reproduced in their entirety by other panel of experts.
- Second, if the choice is not based exclusively on quantitative measurements, it is difficult to classify products in increasing or decreasing order.
- Third, the data are not comparable with other industrial data on value added, employment or gross fixed capital formation published by other agencies such as the United Nations Industrial Development Organization (UNIDO).

**Table 13: High tech products list by the OECD**
**(Based on SITC Revision 3 Codes)**

| Product | SITC Codes |
|---|---|
| 1. Aerospace | [7921+7922+7923+7924+7925+79293 +(714-71489-71499) +87411] |
| 2. Computers-office machines | [75113+75131+75132+75134+(752-7529)+75997] |
| 3. Electronics-telecommunications | [76381+76383+(764-76493-76499)+7722+77261+77318+ 77625+7763 +7764+7768+89879] |
| 4. Pharmacy | [5413+5415+5416+5421+5422] |
| 5. Scientific instruments | [774+8711+8713+8714+8719+87211+(874-87411-8742) +88111 +88121+88411+88419+89961+89963++89967] |
| 6. Electrical machinery | [77862+77863+77864+77865+7787+77844] |
| 7. Chemistry | [52222+52223+52229+52269+525+57433+591] |
| 8. Non-electrical machinery | [71489+71499+71871+71877+72847+7311+73131+73135+ 73144+73151+73153+73161+73165+73312+73314+73316+73733+73735 |
| 9. Armament | [891—] |

*Source: Hatzichronoglou, T (1997)*

It is interesting to note that many of the Asian countries such as Malaysia, Singapore, Thailand, the Philippines, the Republic of Korea and the People's Republic of China have rather high high-technology export intensity (Table 14). However, excepting for the People's Republic of China, the Republic of Korea and, to some extent, Singapore, this indicator is not correlated with either the R&D intensity or patent count indicators. In short, the indicator by itself is not a useful one to employ to find out about innovative activity in an NIS. It has to be used along with the other indicators.

**Technology trade balance:** Another indicator that is frequently used is the technology trade balance. This indicates the balance on trade in disembodied technologies between domestic business enterprises, research institutes and foreign business enterprises and research institutes. A positive balance is supposed to indicate that the NIS of the country in question is capable of generating most of the disembodied technologies that it requires. The indicator is computed as absolute figure, but for international comparisons it is better to convert it into an intensity figure by taking the trade balance as a percentage of GDP.

Technology trade balance = (Receipts on royalty and licence fee – Payments on royalty and license fee) ÷ GDP ×100

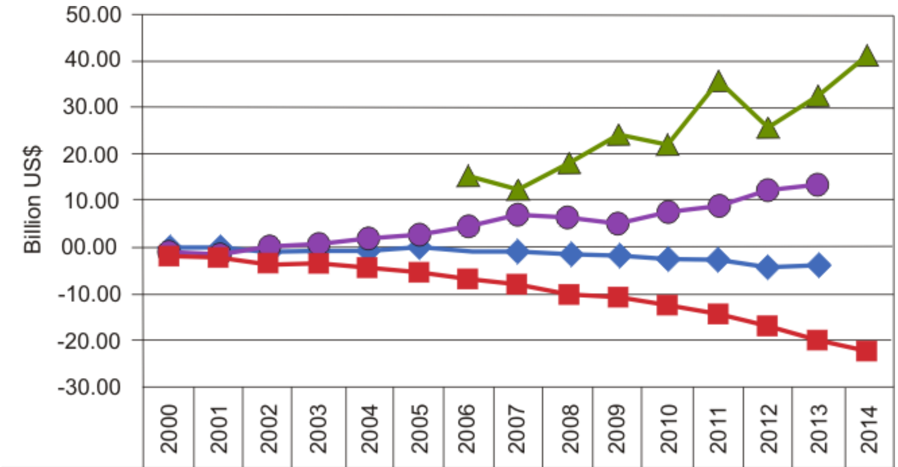
The technology trade balance of four Asian countries is presented in Figure 9. Of the four, the Republic of Korea and Japan have positive trade balance in technology and it correlates with other innovation indicators of these countries, namely R&D intensity, patent counts and high technology exports. In the case of both India and the People's Republic of China, the trade balance is negative although in the case of the latter, the other conventional indicators show a secular increase. In short, the interpretation of this indicator is slightly problematic.

**Table 14: High technology exports intensity of selected Asian countries, 2000-2013 (High technology exports as a percent of manufactured exports)**

| Country | 2000 | 2005 | 2010 | 2013 |
|---|---|---|---|---|
| Bangladesh | 0 | 0 | 0 | — |
| Bhutan | — | 4 | 0 | — |
| India | 6 | 6 | 7 | 8 |
| Sri Lanka | 3 | 2 | 1 | 1 |
| Maldives | — | 0 | — | — |
| Nepal | 0 | — | 1 | 0 |
| Pakistan | 0 | 1 | 2 | 2 |
| Australia | 15 | 13 | 12 | 13 |
| Brunei Darussalam | — | — | — | 15 |
| People's Republic of China | 19 | 31 | 28 | 27 |
| Fiji | 0 | 3 | 3 | 2 |
| Hong Kong, China | 23 | 16 | 16 | 12 |
| Indonesia | 16 | 17 | 10 | 7 |
| Japan | 29 | 23 | 18 | 17 |
| Cambodia | 0 | 0 | 0 | 0 |
| Kiribati | — | — | 43 | 1 |
| Republic of Korea | 35 | 32 | 29 | 27 |
| Macao, China | 1 | 1 | 0 | — |
| Myanmar | — | — | 0 | — |
| Mongolia | 0 | 0 | — | 16 |
| Malaysia | 60 | 55 | 45 | 44 |
| New Caledonia | 1 | 1 | 1 | — |
| New Zealand | 10 | 10 | 9 | 10 |
| Philippines | 73 | 71 | 55 | 47 |
| Papua New Guinea | 19 | — | — | — |
| French Polynesia | 8 | 13 | 5 | 8 |
| Singapore | 63 | 57 | 50 | 47 |
| Solomon Islands | — | — | — | 13 |
| Thailand | 33 | 27 | 24 | 20 |
| Timor-Leste | — | 0 | — | 10 |
| Tonga | 0 | — | 0 | — |
| Tuvalu | — | 15 | — | — |
| Viet Nam | 11 | 5 | 9 | 28 |
| Vanuatu | 0 | — | 14 | — |
| Samoa | — | 9 | 0 | 1 |

*Source: The World Bank (2015)*

**Figure 9: Technology trade balance of India, People's Republic of China, Republic of Korea and Japan**




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| India | -0 | -0 | -0 | -0 | -0 | -0 | -0 | -1 | -1 | -1 | -2 | -2 | -3 | -3 | |
| China | -1 | -1 | -2 | -3 | -4 | -5 | -6 | -7 | -9 | -1 | -1 | -1 | -1 | -2 | -2 |
| Korea | | | | | | | 15 | 12 | 18 | 24 | 22 | 36 | 25 | 32 | 41 |
| Japan | -0 | -0 | -0 | 1 | 2 | 2 | 4 | 7 | 6 | -5 | 7 | 9 | 12 | 13 | |

*Source: Computed from United Nations Service Trade Statistics Database*

Based on the data and the discussion presented, two propositions may be in order:

**Proposition 1**: All countries with a positive technology trade balance are innovative, e.g., the Republic of Korea, Japan and the United States.

**Proposition 2**: All countries with a negative technology trade balance need not necessarily be non-innovative, e.g., the People's Republic of China.

We will now return to the discussion of input-based indicators. The two remaining indicators that need to be discussed are density of scientists and engineers and venture capital investments.

**Density of scientists and engineers:** One of the key input factors to innovative activity in an NIS is the availability of good quality scientists and engineers. A critical minimum number of scientists and engineers is required for a nation to innovate. The conventional indicator taken is the density of scientists and engineers – the number of scientists and engineers per unit of labour force, usually in terms of 1,000 or 10,000 labour force. Table 15 presents data on the density of R&D personnel for a range of countries. It is also seen that the countries that are innovative, for instance Japan and the Republic of Korea, have larger and growing densities. In fact, one can see a positive correlation between density and research intensity. Although this indicator is usually suggested as an innovation indicator, it is rarely used as one. This is because the interpretation of the direction of movement of the indicator is not straightforward. Density may be low because of a variety of reasons affecting both the supply and demand for R&D personnel. However, nations may do well to monitor this indicator, as the supply of R&D scientists is a necessary requirement for a country to innovate.

**Table 15: Trends in the density of R&D researchers (per 1,000 labour force on FTE basis)**

| Country | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| People's Republic of China | 1.26 | 1.29 | 1.39 | 1.46 | 1.52 | 1.79 | 1.96 | 2.25 | 2.53 | 2.93 | 3.26 | 3.64 | 4.07 | 4.39 |
| Hong Kong, China | 2.88 | 3.19 | 3.66 | 4.77 | 5.3 | 6.16 | 6.36 | 6.48 | 6 | 6.31 | 6.57 | 6.64 | 6.82 | - |
| Macao, China | - | 0.86 | 0.86 | 1.08 | 1.43 | 1.61 | 1.53 | 1.36 | 1.42 | 1.7 | 2.03 | 2.1 | 2.28 | 2.72 |
| India | 0.78 | - | - | - | - | 0.84 | - | - | - | - | 0.94 | - | - | - |
| Indonesia | 0.57 | 0.51 | - | - | - | - | - | - | - | - | - | - | - | - |
| Japan | 13.39 | 12.99 | 12.54 | 12.96 | 13.2 | 13.54 | 13.73 | 13.71 | 13.29 | 13.28 | 13.23 | 13.33 | 13.08 | 13.24 |
| Lao People's Democratic Rep. | - | - | 0.11 | - | - | - | - | - | - | - | - | - | - | - |
| Malaysia | 1.03 | - | 1.05 | - | 1.67 | - | 1.2 | - | 1.92 | 3 | 4.18 | 4.62 | 4.93 | - |
| Mongolia | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Myanmar | - | 0.17 | 0.29 | - | - | - | - | - | - | - | - | - | - | - |
| Nepal | - | - | 0.52 | - | - | - | - | - | - | - | - | - | - | - |
| Pakistan | - | - | - | - | - | 1.07 | - | 1.3 | - | 1.32 | - | 1.17 | - | 1.19 |
| Philippines | - | - | - | 0.27 | - | 0.27 | - | 0.26 | - | - | - | - | - | - |
| Republic of Korea | 6.2 | 7.34 | 7.49 | 8.08 | 8.24 | 9.03 | 9.88 | 11.09 | 12.07 | 12.66 | 13.52 | 14.37 | 15.49 | 15.48 |
| Singapore | 9.62 | 9.43 | 10.39 | 10.8 | 11.33 | 12.12 | 12.19 | 12.6 | 12.53 | 13.18 | 13.12 | 13.4 | 13.11 | - |
| Sri Lanka | - | - | - | - | 0.7 | - | 0.53 | - | 0.67 | - | 0.69 | - | - | - |
| Thailand | - | 0.9 | - | 1.16 | - | 0.98 | - | 1.1 | - | 1.55 | - | 1.35 | - | - |
| Viet Nam | - | - | 0.25 | - | - | - | - | - | - | - | - | - | - | - |

*Source: Compiled from UNESCO Institute of Statistics, http://data.uis.unesco.org/Index.aspx?queryid=61# (accessed on 26 November 2015)*

**Venture capital investments:** An important, but not always appreciated, aspect of innovative activity in an NIS is the fact that the quantity of innovations in an NIS is equal to innovations done by existing firms and new innovative start-ups. This could be expressed as follows:

Innovations in an economy = Innovations by existing business enterprises + New innovative start-ups

Venture capital (VC) plays an important role in financing new innovative start-ups although the degree to which it does varies from one country to another. VC is a particularly important form of equity financing (i.e. equity capital provided to firms not quoted on the stock market) for young companies with innovation and growth potential, replacing and or complementing traditional bank finance (See Box 3). For instance, VC plays a very important part in financing innovative start-ups in the United States and in Israel, but to a lesser degree in Western Europe and in developing Asia. So the indicator, venture capital investments as a percentage of GDP, is a good one for measuring the quantity of new innovative start-ups that are created in an NIS. There are, however, two major limitations to this indicator that can dampen its widespread usage. First, as mentioned in Box 3, there is no harmonized definition of what exactly VC is. There is thus a tendency to club VC with private equity, which is problematic as an innovation indicator. Second, almost all data sources on VC are private sources and therefore not freely available. For Asian countries, the main source for VC data is *Asian Venture Capital Journal*.

Governments play a crucial role both in creating the right funding ecosystem for entrepreneurial and start-up businesses and in providing them with vital funding that complements private VC. According to the *EY G20 Entrepreneurship Barometer 2013*, entrepreneurs say the second most important funding source after bank credit for fuelling entrepreneurship is public aid and government funding. Brander, Du and Hellman (2014) find that enterprises funded by both government-sponsored venture capitalists (GSVCs) and private venture capitalists (PVCs) obtain more investment than enterprises funded purely by PVCs, and much more than those funded purely by GSVCs. Also, markets with more GSVC funding have more VC funding per enterprise and more VC-funded enterprises, suggesting that GSVC finance largely augments rather than displaces PVC finance. There is also a positive association between mixed GSVC/PVC funding and successful exits, as measured by initial public offerings (IPOs) and acquisitions, attributable largely to the additional investment.

### Box 3: What is Venture Capital?

Venture capital is a subset of the private equity industry and refers to equity investments made to support the pre-launch, launch and early stage development phases of a business. In the OECD Entrepreneurship Financing Database, venture capital comprises the sum of early stage (including pre-seed, seed, start-up and other early stages) and later stage venture capital. As there are no internationally harmonized definitions of venture capital stages across venture capital associations and other data providers, original data have been re-aggregated to fit the OECD classification venture capital by stages.

*Source: OECD*

Perhaps a celebrated example of the government's role in funding innovative projects, which later became a world standard, is the algorithm that led to Google's early success and was funded by the United States' National Science Foundation (NSF). The positive news is that governments across the world are improving access to VC funding and improving the start-up ecosystem in general. India is one such country that now has an official start-up policy and the VC investments in the country have increased from US$ 600 million in 2006 to US$ 1.8 billion in 2013 (Earnest and Young 2014).

**Measuring production of scientific knowledge through bibliometric data:** All the output indicators discussed earlier measure the output of innovation in terms of tangible products. However, it is also important to measure an NIS's production of scientific knowledge, as it is an important measure of a nation's science and technological activity. The Institute for Scientific Information (ISI), which is now a part of Thomson Reuters, maintains citation databases covering thousands of academic journals, including a continuation of the Science Citation Index (SCI), its long-time, print-based indexing service. This database allows a researcher to identify which articles have been cited most frequently and by whom. The database provides some measure of the academic impact of the papers indexed in it, and may increase their impact by making them more visible and providing them with a quality label. SCI covers more than 6,500 notable and significant journals across 150 disciplines from the year 1900 to the present. These journals are described as the world's leading journals of science and technology, because of a rigorous selection process. The index is made available online through different platforms, such as the Web of Science.

From this bibliographic database the following indicators can be analysed for a specific NIS: (1) total number of publications; (2) world share of publications; (3) publications per million inhabitants; and (4) publications with international co-authors. While the first three help us to understand the total quantity of science production and its distribution across various scientific disciplines, the fourth one help us analyse the globalization of science production in a country. The main negative feature of the SCI index is that it is a priced publication necessitating a subscription to the database which is very costly.

According to UNESCO World Science Report 2015, between 2008 and 2014, the number of scientific articles catalogued in the SCI Web of Science grew by 23 per cent from 1,029,471 to 1,270,425. Growth was strongest among the upper middle-income economies (94 per cent), primarily driven by growth in publications from the People's Republic of China (151 per cent). The United States was the single largest country of origin, with 321,846 scientific articles in 2014, or 25.3 per cent of world total, down from 28.1 per cent in 2008, whereas the People's Republic of China's share climbed from 9.9 per cent to 20.2 per cent over the same period. The Islamic Republic of Iran nearly doubled its share of world publications to 2 per cent in 2014, with 25,588 articles, comparable to the world shares of the Arab states (2.4 per cent), Russian Federation (2.3 per cent) and Turkey (1.9 per cent). Scientific articles by Malaysian authors grew by 251 per cent between 2008 and 2014, to reach 9,998, or 331 articles per million inhabitants – around three times the average of Asia as a whole.

Japan remained a major source of scientific publishing in 2014 (73,128 articles, or 5.8 per cent of the world total), but it is one of the rare countries where output has declined (by 4.1 per cent since 2008). Another example of this trend is Venezuela, where scientific output declined by as much as 28 per cent between 2005 and 2014.

**Measuring innovations in new and emerging technologies:** An interesting aspect of modern times is the emergence of new technologies such as information technology, biotechnology and nano technology, new types of materials, and a number of renewable energy technologies. These are the new technologies that have diffused in developed countries of Asia. However, what is considered as new and emerging technologies need not be the new and emerging ones of today. The World Economic Forum's Meta-Council on Emerging Technologies, a panel of 18 experts, drawing on their collective expertise of the Forum's numerous communities, identified ten technologies (See Box 4) as new and emerging in the world as a whole although most of these or none of these are being developed by developing country institutions or firms.

**Box 4: New and emerging technologies (c 2015)**

| | Type of technology | Description of technology |
|---|---|---|
| 1. | Fuel cell vehicles | Zero-emission cars that run on hydrogen |
| 2. | Next-generation robotics | Rolling away from the production line |
| 3. | Recyclable themoplastics | A new kind of plastic to cut landfill waste |
| 4. | Precise genetic-engineering techniques | A breakthrough offers better crops with less controversy |
| 5. | Additive manufacturing | The future of making things from printable organs to intelligent clothes |
| 6. | Emergent Artificial intelligence | Computers that learn on the job |
| 7. | Distributed manufacturing | Online- factories of the future |
| 8. | 'Sense and avoid drone' | Develop machine that can fly on their own without a pilot |
| 9. | Neuromorphic technology | Computer chips that can mimic human brain |
| 10. | Digital genome | Health care for an age when your genetic code is on a USB stick |

*Source: Meyerson (2015), http://www.scientificamerican.com/article/top-10-emerging-technologies-of-20151/ (accessed on 6 January 2016)*

An indicator for measuring new technologies does not exist as of now. Therefore, it is suggested that countries first define what constitutes "new and emerging technologies" and then compute their relative share in total manufacturing value added. The indicator that is suggested is:

New and Emerging Technology Indicator = (Value added of new and emerging technologies ÷ Total manufacturing value added) × 100

**Further indicators for measuring environment quality and gender mainstreaming:** Fostering innovation is one of the sustainable development goals of the United Nations. Besides, improving the quality of environment and gender mainstreaming are two of the important pillars of SDGs.

**Environmentally Sound Technology Innovations:** A large number of indicators are available for measuring environment (OECD 2008). However, what we require are innovations in environmentally sound technologies (ESTs), which encompass technologies that have the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, ESTs:

- Protect the environment;
- Cause less pollution;

- Use resources in a sustainable manner;
- Recycle more of their wastes and products; and
- Handle all residual wastes in a more environmentally acceptable way than the technologies they substitute for.

One could apply the innovation indicators developed above – such as R&D expenditure, patents and technology trade balance – to ESTs to derive EST-specific innovation indicators. The major constraint is, of course, data availability, as most developing countries report data on ESTs excepting for renewable energy technologies like wind and solar energy.

**Indicators for measuring gender mainstreaming in innovative activity:** Women's participation in the labour force is an important determinant of sustainable development. Unfortunately, this is declining in many developing countries despite improvements in women's literacy and health levels. Hence, an important focus variable is the number of women participating in the science and engineering workforce. The indicators that are relevant for us are the following:

1. Female researchers as a per cent of total researchers, both on full-time equivalent (FTE) and head count bases, in business enterprises, higher education, government and private non-profit institutions. See Table 16 for available data across a few Asian countries.
2. Female researchers as a per cent of total researchers in various technology arenas, such as natural sciences, engineering technologies, and medical and health sciences.

It is seen that the share of women researchers are traditionally high in biology and health sciences. The challenge is to improve the share of women researchers in fields of engineering and technology. Constant monitoring of these variables will help.

In this step, we have surveyed a range of innovation indicators that have the potential of measuring innovations by existing as well as new business enterprises. The indicators fall into two broad categories: input (R&D expenditure, density of R&D personnel, VC investments) and output (patents, high technology exports and technology trade balance). Our discussions of these various indicators revealed, in an implicit manner, four criteria that must be satisfied for choosing an indicator for measuring the performance or health of an NIS. These are:

- It must be *easy to interpret* and must measure either the input or output of innovative activity that goes on among the various actors of an NIS;
- The *data for its computation must easily be available* so that one can compute it and on the basis of which the health of an NIS can be monitored regularly;
- There must exist a *harmonized definition* of it so that international comparisons are possible; and
- It must *provide additional insights* about the innovation process so that one can measure, even as a first approximation, the nature of interactions that takes place between the various actors of the NIS.

None of the six indicators that we surveyed and discussed meet with the above four criteria. But among the imperfect proxies, the two that come closer to satisfying most of the four conditions are R&D expenditure and patents. We have indicated the relative merits and demerits of these two universal innovation indicators and have also provided the sources of data for these two.

**Table 16: Share of female researchers across the various actors in an NIS in selected Asian countries**

| Year | Cambodia | Macao, China | India | Islamic Republic of Iran | Malaysia | Pakistan | Philippines | Sri Lanka | Thailand |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | - | - | 12.0 | - | 31.8 | - | - | - | - |
| 2001 | - | 17.1 | - | - | - | - | - | - | - |
| 2002 | 22.6 | 15.4 | - | - | 34.2 | - | - | - | - |
| 2003 | - | 18.2 | - | - | - | - | 52.7 | - | - |
| 2004 | - | 19.7 | - | - | 37.1 | - | - | 32.1 | - |
| 2005 | - | 25.8 | 14.8 | - | - | 16.2 | 50.8 | - | 49.9 |
| 2006 | - | 27.9 | - | 24.0 | 38.8 | - | - | 41.1 | - |
| 2007 | - | 27.4 | - | - | - | 23.4 | 50.8 | - | 50.7 |
| 2008 | - | 30.4 | - | 27.6 | 41.2 | - | - | 38.9 | - |
| 2009 | - | 29.7 | - | 24.2 | 47.7 | 23.7 | - | - | 50.3 |
| 2010 | - | 33.2 | 14.3 | 27.0 | 46.1 | - | - | 39.3 | - |
| 2011 | - | 36.0 | - | - | 45.8 | 23.6 | - | - | 53.1 |
| 2012 | - | 32.0 | - | - | 47.0 | - | - | - | - |
| 2013 | - | 32.2 | - | - | - | 31.3 | - | - | - |

*Source: UNESCO Institute of Statistics*

## Step 4: Designing Policy Instruments to Encourage Innovation

In this step, we are primarily concerned with the designing of policy instruments to impact upon innovative activity in business enterprises. However, as seen earlier, total number of innovations in an economy is composed of innovations by existing business enterprises plus new innovative ventures coming on stream. Much of the innovation policy instruments that we discuss are targeted squarely at promoting innovations by existing enterprises by encouraging them to commit more resources to innovation activity such as R&D. Promoting new innovative ventures through improving the ecosystem for venture creation too is discussed. Improving the so called ecosystem for venture creation consists of two policies (i) improving the ease of doing business so that new ventures can be created with relative ease; and (ii) financial and other support mechanism for new innovative venture creation. The most important component this is the establishment and nurturing of venture capital institutions.

Before we go on to discussing various policy instruments, we must first understand why knowledge production is prone to market failures. The market failure reduces the actual level of knowledge production from its optimum level in a given economy.

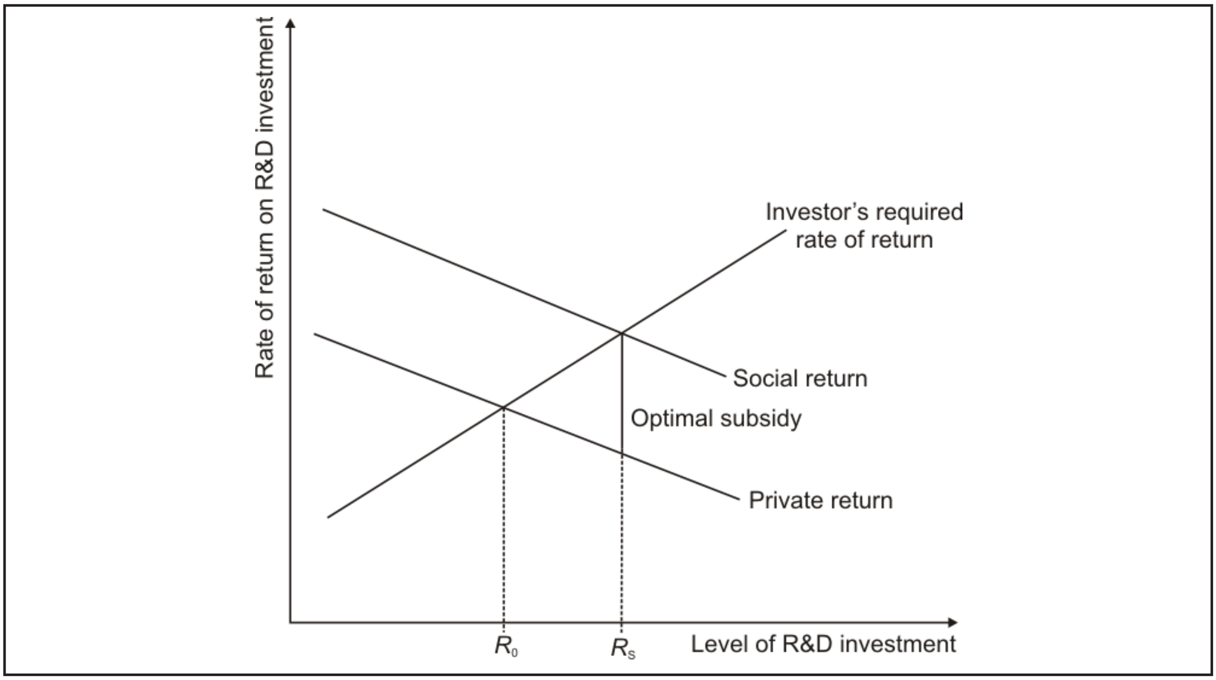
### Rationale for policy intervention

Knowledge production is characterized by two kinds of market failures, which result in under-investment in R&D by firms – actual level of investment being less than the optimum level. This may result in lesser economic growth and so is welfare-reducing, especially in business enterprises, and must be corrected through public policy instruments. This is discussed in detail below.

***Market failure number 1***

This is a situation where the business enterprises fail to finance its own intramural R&D due to its inability to appropriate the full return to its own research efforts. This is because knowledge has public good characteristics, namely: (1) it is non-rivalrous – several individuals can use knowledge without diminishing its value; and (2) it is non-excludable – an individual cannot be prevented from consuming knowledge. Given this public good nature, there can be under-investments in knowledge production. A more formal way of stating this possibility of under-investment is by invoking the appropriability[1] problem. The creator of knowledge fails to appropriate the full returns from her own research because knowledge leaks, despite patent protection. This could be explained graphically using a simple diagram (Figure 10). Without any subsidy, private investors equate their expected private return to their required rate of return and the result is a level of investment of **R0**. The socially optimal level of R&D investment is where the social return is equated to the opportunity cost of funds. The social return is higher due to the positive externalities of R&D. With a subsidy to R&D, the government effectively raises the private return to equal the social return and so the private investors now choose the socially preferred higher level of investment **Rs**.

**Figure 10: Role of R&D subsidy in correcting market failure**

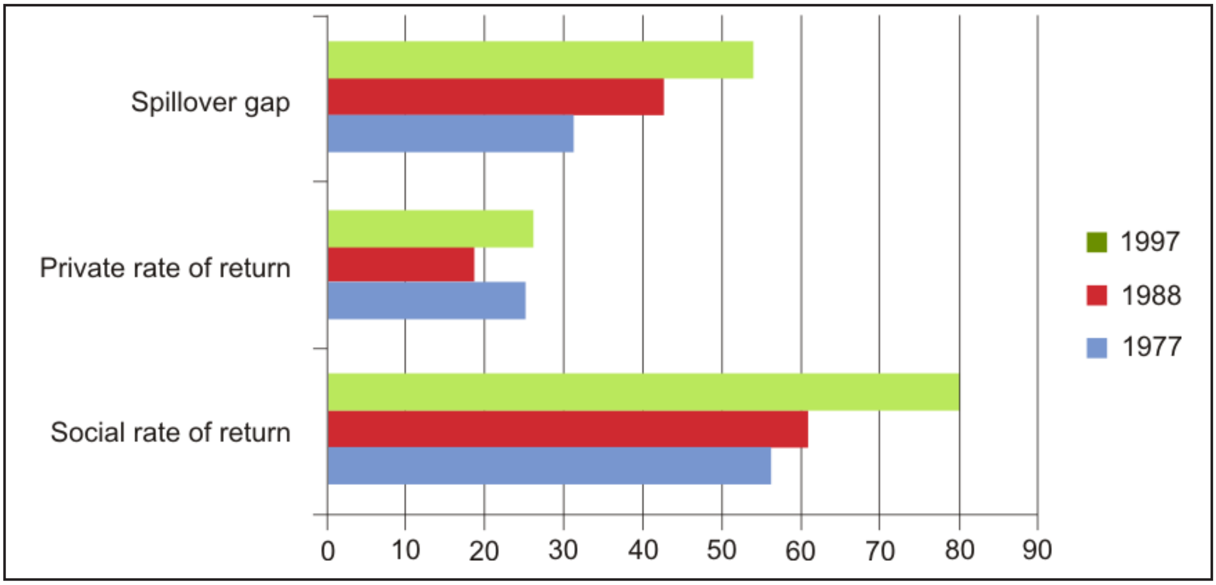



*Source: Greenhalgh and Rogers (2010), p.25*

[1] Appropriability is a firm's capacity to fully appropriate the added value that it creates for its sole benefit.

When the knowledge produced by a business enterprise is imitated by another, the private rate of return that the original firm would have obtained gets reduced. As a result of increased competition between the original innovator and the new imitators, the price of the innovation (say a new drug) actually goes down. This reduction in the price of the new drug (say) actually reduces the societal rate of return. The difference between the private rate of return and the societal rate of return is called the spillover gap. Larger the spillover gap, larger is the desire of business enterprises to under-invest in new technologies. See Figure 11 for some estimates of the spillover gap.

**Figure 11: Spillover gap**




*Source: Mani (2002)*

***Market failure number 2***

R&D is an uncertain activity in terms of output. When something is uncertain, you cannot even attach a probability to its potential outcome. Hence, the conventional capital market (whether debt or equity market) tends to eschew R&D projects. Since it is difficult to fund R&D, actual level of R&D performed is less than the optimum level. This is the second market failure. The policy response to this is the creation of specialized financial institutions such as venture capital and conditional loans – loans that carry a rate of interest less than the market rate.

Figure 12 summarises the two types of market failures in the financing of innovation and the policy response to it.

**Taxonomy of policy instruments**

Innovation policy is designed to overcome these market failures. It consists of a set of instruments and institutions that is designed to encourage firms to increase investments in intra mural R&D.

**Figure 12: The two market failures and policy response to correct it**

| Policy instruments to deal with the two market failures | |
|---|---|
| **First market failure** | **Second market failure** |
| ■ Have a strong IPR regime preventing leakages of ideas<br>■ Provide a subsidy to firms in the form of research grants and tax subsidies | ■ Have specialized financial instruments which are designed to finance innovations<br>■ An example of these is conditional loans, but the most common one is venture capital |

The policy instruments can be divided into three types based on who is funding the instrument (public or private sector) and based on its actual execution. Employing the criteria of both funding and execution, the following three types of policy instruments are normally encountered:

- Type 1: Publicly funded and executed – Public-funded innovation carried out by academic institutions and public research organizations;
- Type 2: Publicly funded but privately executed – Governments can fund research undertaken by private firms, notably through public technology procurement, research subsidies, soft loans, R&D tax credits and innovation prizes; and
- Type 3: Privately funded and executed – The intellectual property system is the one mechanism that promotes privately executed R&D, which is financed through the market place rather than through government revenues.

Of these three types, the most commonly used are instruments of Type 3 and within that type, the most popular instruments are R&D tax incentives, research grants and public technology procurement. We will be discussing these three instruments in some more detail below.

**Complementarity between policy instruments**

Various instruments of innovation policy can be complementary. For instance, academic research sometimes results in patents and subsequent licensing for commercial development. Similarly, government support of privately undertaken research may result in intellectual property ownership. Countries have also used research grants and R&D tax incentive as complementary. For instance, grants are used so that firms can actually learn how to do R&D and when they have learned it adequately, R&D tax incentives are provided to encourage the firms to do more R&D. Also, instruments are tied to the stage of development of a country. Countries that are at the lower end of the technology ladder may use instruments such as research grants and public technology procurement to stimulate R&D and when they move up the ladder, use more of the R&D tax incentive variety.

**Three different Type 3 policy instruments for promoting innovations by existing business enterprises**

***(1) R&D tax incentives***

This is by far the most popular policy instrument encountered and it is one of the ways by which the natural inclination for business enterprises to under-invest in R&D (compared with an optimum level) is reversed. R&D tax incentives are expected to lead not only to higher R&D expenditure but also to higher innovative outcomes (that is, more product and process innovations), higher sales from innovative products or more patents, and increased productivity in the long term.

With reference to R&D tax incentives, we will discuss the following issues: (a) type of R&D tax incentives; (b) measuring its size, generosity and effectiveness; and (c) its comparison, in terms of advantages and disadvantages, with research grants as an instrument for promoting innovations.

(a) Types of R&D tax incentives

R&D tax incentives appear in two forms: level or volume; and incremental. A level or volume scheme provides tax relief on the total amount of R&D (although there may be upper limits). An incremental system gives tax relief on increases in R&D over a base figure. The base figure can be calculated in various ways, such as average R&D expenditure over the last three years, but its central objective is to increase R&D spending. A level or volume R&D tax incentive is more straightforward to implement, but does give tax relief on R&D that would have been conducted any way. Box 5 summarises the main issues in the design of R&D tax incentives.

### Box 5: Design issues with respect to R&D tax incentive

**The target group**

Governments can make fiscal support accessible to all companies, or make support more generous for target groups of firms (e.g. SMEs). This can be done by:

- Placing upper limits on the amounts of tax credit that can be claimed (upper limits are more likely to be attained by larger companies than by SMEs).
- Giving higher tax credits rates for SMEs, and/or greater flexibility e.g. cash refunds or unused credits. Minimum thresholds can increase the efficiency of policy as administrative costs can be high for small applications.

Labelling of activities and claiming the tax credit: The definition of R&D is typically based on the Frascati Manuel (OECD,2002). However, most countries have produced their own list of types of R&D that qualify.

**Qualified R&D expenditure**

Three types of expenditure can qualify for fiscal incentives:

- Expenditure on wages related to R&D. This reduces social security and wage taxes and gives an incentive investment in human capital.
- Current R&D expenditure. This includes wages and all consumables used in the R&D process.
- Current and capital R&D expenditure: This enlarges the incentive for companies, but increases the public cost of the policy.

The base amount of incremental tax credit:can take two forms:

- Rolling average base – The base amount is computed as the average R&D expenditure of the previous x years.
- Fixed base – The base amount equals the average R&D expenditures during a fixed reference period. This average can then be indexed to sales or inflation to stay relevant.

Carry-over provisions and cash refunds:These provisions allow unused portions of the credit to be carried forward or backward to previous fiscal years. Carry forward provisions are particularly important for SMEs, as these tend to have limited current corporate income against which the credit can be applied, while many younger firms are carrying losses from previous periods. Cash refunds can also replace carry forward provisions. The time value of the funds should be taken into account when calculating refunds. Delays in effecting cash refunds need to be avoided in order to making his tool efficient.

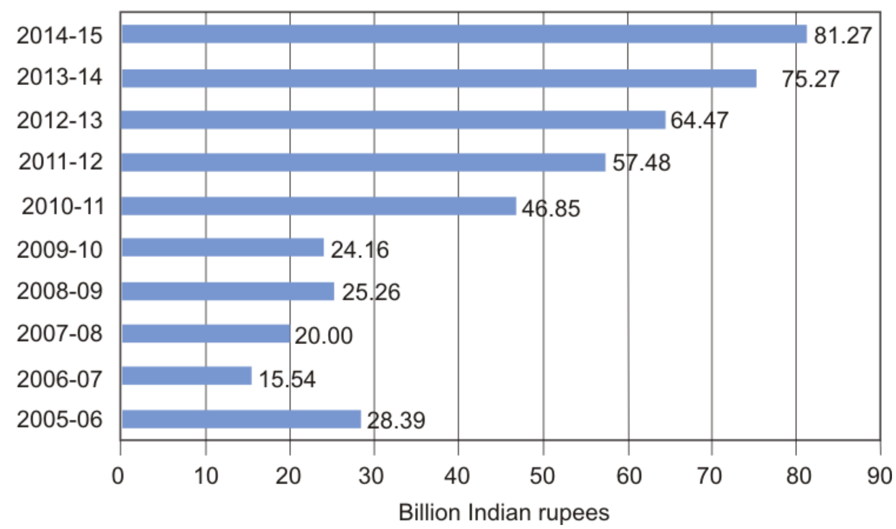
*Source: OECD (2010), p.4*

(b) Measuring R&D tax incentives

*Measuring size:* Measuring the size of this subsidy is not very straightforward, as there are no flows of subsidy that go from the exchequer to the business enterprise. Instead, it can be observed through the amount of corporate income tax that is lost as a result of the subsidy. The amount of tax lost due to the operation of this subsidy will have to be estimated first. Fortunately, most governments are now engaged in the estimation of this tax lost. One such government is that of India's, which has been regularly computing the amount of tax lost due to the operation of a number of subsidies that are directed towards the corporate sector. Using these estimates, we have been able to derive the size of the R&D tax incentive in India. See Figure 13.

R&D tax incentive = Tax foregone due to the operation of this subsidy scheme

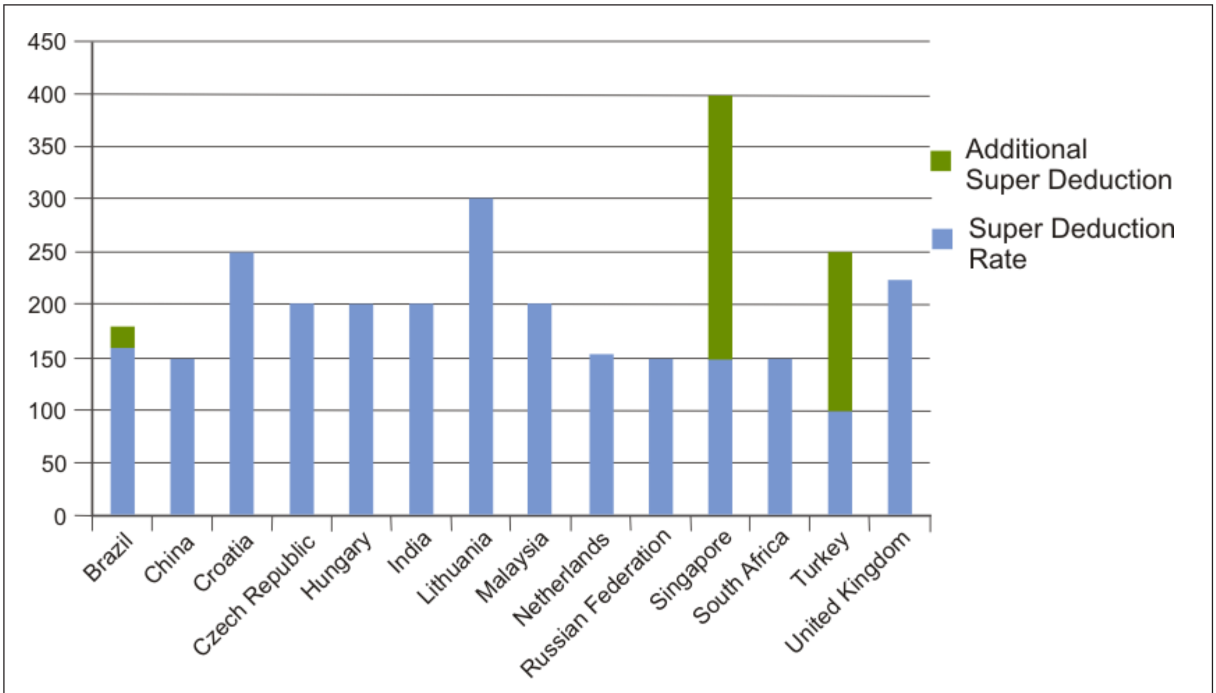
**Figure 13: The size of R&D tax incentive in India**




*Source: Compiled from India's budget documents*

*Measuring generosity:* Many countries – including some of the leading developing countries in Asia such as Malaysia, India and Singapore – offer tax deductions that are more than 100 per cent. When it is more than 100 per cent, we term it as "super deductions". Figure 14 maps out the countries that offer super deductions.

**Figure 14: Countries offering super deductions in R&D tax incentive (c2014)**

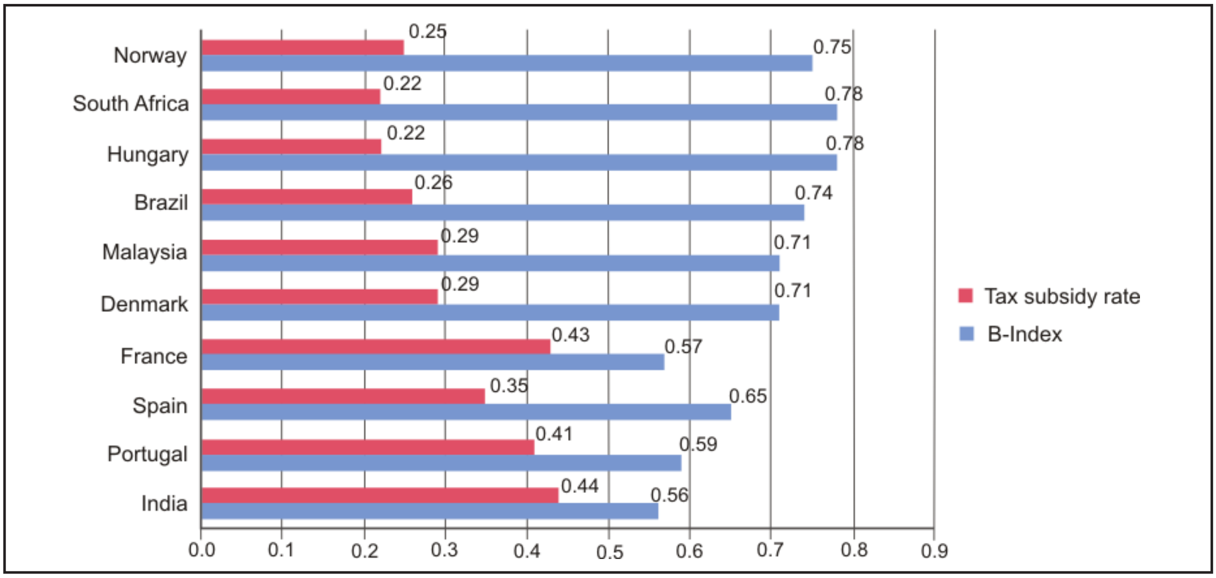



*Source: Deloitte (2014)*

However, generosity of a tax regime depends not just on the extent of tax deductions that are available but also on the corporate income tax rate. Hence, a summary measure or index called the B-index has been developed by analysts to measure generosity of a tax regime. There are essentially two separate but related indices: the B-Index and the Tax Subsidy Rate. The B-index represents the before tax rate of return on one dollar of R&D investment, in present value terms. For easy interpretation, the B Index is often reported as the 'tax subsidy ratio' (1-B Index), which is, simply put, the proportion of 1 dollar of R&D expenditure that is subsidized by tax incentives. Negative tax subsidy ratio reflect cases where there are no tax incentives and capital assets employed in R&D cannot be written off in the year they were incurred, but rather are depreciated over time. India has one of the lowest B-indices among the major R&D tax providing countries in the world. See Figures 15 (a) and (b) for both SMEs and large firms, respectively. Box 6 gives some examples of computing B-Index.

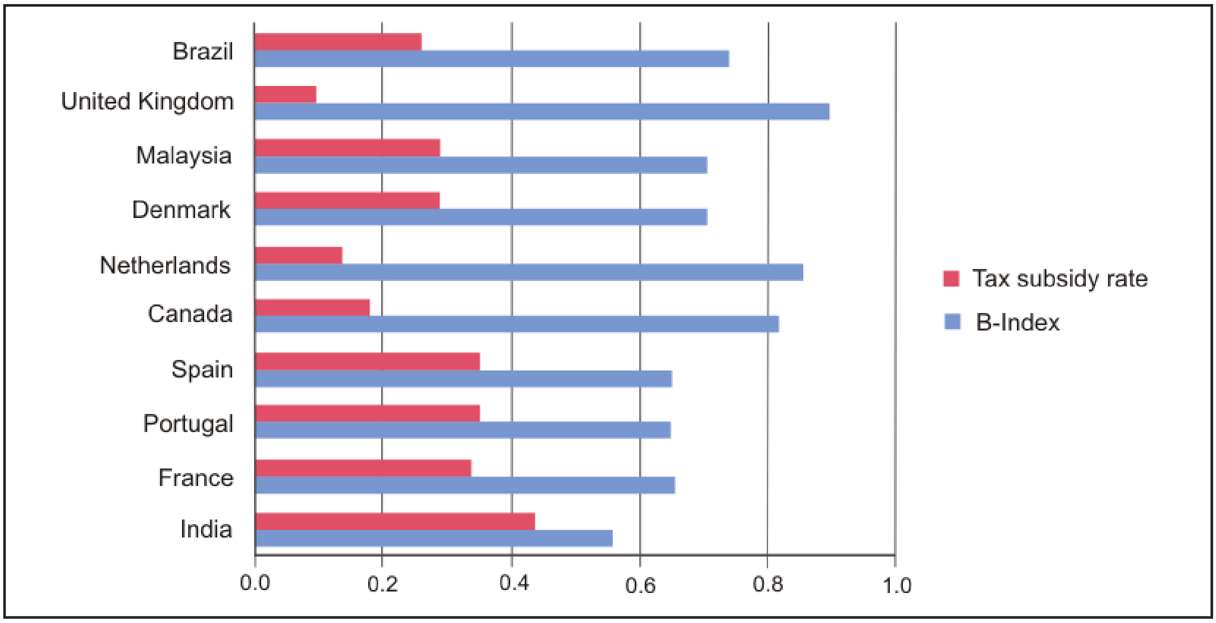
There, however, exists no estimate of rank correlations between the research intensity of business enterprises in a country and the generosity of the R&D tax regimes. India has one of the most generous R&D tax regimes in the world, but Indian business enterprises have low research intensities, with the exception of pharmaceutical enterprises and a few isolated cases in other sectors.

**Figure 15 (a): B-index across countries (SMEs), 2012**




*Source: Mani (2014)*

**Figure 15 (b): B-index across countries (Large firms), 2012**




*Source: Mani (2014)*

**Box 6: Some examples of computing B-index**

Generic example:

B-Index = (1–A)/(1–t)

Where

A = the net present discounted value of depreciation allowances, tax credits and other R&D tax incentives available (i.e., after-tax cost)

t = corporate income tax rate

Country-specific examples:

Canada, B = (1– xt – yzt – c(1–t))/(1–t)

France, B = (1– xt – yzt – c)/(1–t)

Where

x = proportion of current R&D expense

y = proportion of capital R&D expense

z = PV of depreciation

c = tax credit

t = tax rate]

*Measuring effectiveness:* Diverse methods have been used for measuring the effectiveness of R&D tax incentives. For the purpose of policy assessment, firms cannot legally be excluded from a tax incentive to which they are entitled. This removes the possibility of evaluating R&D tax credits by constructing a control group using randomisation techniques. Evaluations have therefore been based on the following four approaches: surveys; quasi-natural experiments; techniques using statistically constructed control groups; and structural econometric modelling. An econometric technique that is commonly used is to measure the elasticity of R&D expenditure with respect to a unit reduction in the cost of performing R&D. If the coefficient of this elasticity is greater than unity, we say that the tax incentive has been effective in spurring additional amounts of R&D investment. On the contrary, if it is less than unity, the incentive has not been effective in increasing R&D expenditure proportionately more than the amount of tax foregone. Furthermore, if it is just equivalent to unity, the tax incentive has been neutral.

Elasticity of R&D expenditure = Proportionate change in R&D ÷ Proportionate change in tax foregone

Another interesting question to be empirically answered is whether super deductions always promote significant increases in R&D. Empirical evidence is lacking on this. This is because R&D intensity depends on a number of other determinants like the availability and quality of R&D personnel, the demand for innovation arising from increased competition between firms, etc. So subsidy per se may not increase additional investments in R&D, if the other sufficient conditions are absent.

However, it must be emphasized that these quantitative estimates are a narrow way of measuring the effectiveness of the R&D subsidy scheme. It is also important to see if the additional amounts of R&D created through the operation of the scheme have been helpful in promoting additional employment generation and exports. However, an evaluation of the operation of this scheme is absolutely essential before its continuation can be decided up on.

There are a few mitigating factors to be borne in mind while introducing R&D tax incentives. These are:

- Firms might "re-label" their outlays following the introduction of a tax incentive. They might re-label some of their existing non-R&D activities as R&D investment. This would lead to a spurious increase in measured R&D. The available evidence suggests that the incidence of this factor is relatively small, particularly in the long term.
- The introduction of an R&D tax incentive would likely cause an increase in the wages of scientists and engineers, due to the inelastic supply of such workers, at least in the short run. Part of the potential benefits of the R&D tax incentives are therefore "eroded" by an increase in the volume R&D performed;
- Finally, projects financed through R&D tax incentives might be those with the lowest marginal productivity. If there are decreasing marginal returns to R&D, the additional R&D induced by an R&D tax incentive might be less productive.

(c) Comparison with research grants

R&D tax incentives are not targeted to a specific group of firms or projects, but rather to all potential R&D performers. They are therefore neutral in terms of industry, region and firm. On the other hand, grants can be directed to specific projects that have high social returns and are more dependent on discretionary decisions by governments. In general, tax credits are used mostly to encourage short-term applied research, while direct subsidies are directed more towards long-term research. Figure 16 summarizes the main advantages and disadvantages of tax incentives in comparison with research grants.

**Figure 16: Comparison of R&D tax incentives and research grants**

Research grants Vs. Tax incentives

| | Pros | Cons |
|---|---|---|
| Tax incentives | Higher political feasibility<br>Less bureaucratic –> More stability<br>Stability of R&D incentive policy | A blunt instrument<br>Inefficient reward for currently finished projects |
| Research grants | Discretion provided to decision makers<br>Reward on a "case-by-case" basis<br>Selective incentive system | Annual budget review<br>Temporary and unstable<br>Require bureaucratic mechanisms |

***(2) Research grants***

Research grants are usually considered the best way of sharing in the risk of the innovator, as the grant amount is never paid back. Although in some cases when the new product or process is released as a result of the grant, a royalty amounting to a percentage of the sales of the new product is paid back to by the grantee. Grants are a direct way of promoting R&D and the outcomes are easily measurable. Governments have used grants to develop strategic and high technologies, where initial amounts required for the development of the new technology and the failure rates are very high that no business enterprise is willing to finance such innovations. Grants can also be used to enable business enterprises know how to carry out R&D. The major disadvantage of research grants is that they are very discretionary. Who gets how much is decided by the grant administrator and this can lead to situations of accumulative advantage and lobbying in securing grants.

Accumulative advantage is described as the process whereby the initial social status of a scientist influences their probability of obtaining a variety of forms of recognition. This leads to those who are well placed enjoying an initial advantage relative to less well-placed peers of equal ability. Once established in a favourable position, a good reputation accrues further advantages disproportionately through the "Matthew Effect" (Box 7) such that on a cumulative basis over time the rich get richer.

Lobbying is very common especially in developing countries where an unholy alliance of sorts is forged between business enterprises and the bureaucracy leading to unfair advantages.

A still another disadvantage of grants is the fact that it is subject to annual budget cuts and so it becomes temporary and unstable.

**Box 7: Matthew Effect**

The term Matthew Effect has been attributed to the sociologist, Robert K Merton. Merton coined the term to show that eminent scientists will get more credit than a comparatively unknown researcher, even if their work is similar. It also means that credit will usually be given to researchers who are already famous.

For more details, see Merton, Robert K (2008), 'The Matthew effect in science', Science, 159 (3810), pp. 56-63.

***(3) Public technology procurement***

This has been used in varying combinations to promote technological learning. An important public procurement combination is when governments procure strategically in cooperation with other partners in order to promote innovative capabilities in their countries. Public technology procurement is used by governments, sometimes, to create national champions.

There are different types of technology procurement, such as:

- Developmental procurement, which refers to procurement that encourages technologies to be developed from the start;
- Adaptive procurement, which aims to encourage innovation of an existing technology so as to customize it to meet the particular need;

- Direct procurement, or acquisitions where the end user of the procurement is the government itself; and
- Catalytic public procurement, wherein a state agency initiates the procurement although the innovation is used exclusively by private parties.

There are two routes through which public technology procurement can assist innovations: (1) Create a market for innovative products and processes, by setting up new performance standards; and (2) Support innovative SMEs by acting as 'early users' of new products (early adopters), providing feedback to help refine and improve their products for eventual supply to a wider market.

***Two different policy instruments for promoting the creation of new innovative ventures***

As discussed earlier, in most countries developing and developed as well, much of the innovations are spurred by new innovative ventures coming on stream. Many of these enterprises start very small and then go on to becoming leading business enterprises in their respective industries. For instance most of the innovative companies that we know of today as Apple, Microsoft, Google, Facebook, Twitter, Amazon etc. started off as small innovative ventures and slowly over time emerged as large companies of today. Two important policy instruments that are common to their establishment, growth and success are: (a) ease of doing business; and (b) financial instruments such as venture capital financing. Together these two improve the ecosystem for new innovative venture creation.

(1) Ease of doing business

The World Bank has been ranking countries on the basis of ease of doing business. Currently the 2016 ranking of 189 countries are available. However, this deals essentially with starting any type of business and not start-ups per se. The only ranking of the ecosystem for start-ups is by the private sector business agency Compass.co, which brings out a ranking called The Global Start-up Ecosystem Ranking. The ranking is based on an index which comprises five major components:

- Performance on the funding and exit valuations of start-ups headquartered in an ecosystem;
- Funding on VC investment in the ecosystem and the time it takes to raise capital;
- Talent on the quality of technical talent, its availability and cost;
- Market reach on the size of the local ecosystem's GDP and the ease of reaching customers in international markets; and
- Start-up experience on first-party survey data that is linked to success of start-ups, such as having veteran start-up mentors or founders with previous start-up experience.

Table 17 ranks the top 20 start-up ecosystems in the world. The 2015 rankings are only indicative as China and Japan are not included. Nevertheless, the concept is useful in assessing the quality of the ecosystem for supporting new technology-based venture creation. Note that the availability of funding – especially of the venture capital – is included as part of the ecosystem. However, given its extreme importance, we will discuss venture capital separately. Many Asian countries have started shoring up their ecosystem for start-ups. A frequently used component of this is the establishment of technology incubators. The recent initiatives in India in this direction are a case in point.

**Table 17: Top 10 start-up ecosystems in the world, 2015**

| Place | Ranking | Change | Performance | Funding | Market Reach | Talent | Start-up Exp. |
|---|---|---|---|---|---|---|---|
| Silicon Valley | 1 | ◄► | 1 | 1 | 4 | 1 | 1 |
| New York City | 2 | ▲3 | 2 | 2 | 1 | 9 | 4 |
| Los Angeles | 3 | ◄► | 4 | 4 | 2 | 10 | 5 |
| Boston | 4 | ▲2 | 3 | 3 | 7 | 12 | 7 |
| Tel Aviv | 5 | ▼3 | 6 | 5 | 13 | 3 | 6 |
| London | 6 | ▲1 | 5 | 10 | 3 | 7 | 13 |
| Chicago | 7 | ▲3 | 8 | 12 | 5 | 11 | 14 |
| Seattle | 8 | ▼4 | 12 | 11 | 12 | 4 | 3 |
| Berlin | 9 | ▲6 | 7 | 8 | 19 | 8 | 8 |
| Singapore | 10 | ▲7 | 11 | 9 | 9 | 20 | 9 |
| Paris | 11 | ◄► | 13 | 13 | 6 | 16 | 15 |
| Sao Paulo | 12 | ▲1 | 9 | 7 | 11 | 19 | 19 |
| Moscow | 13 | ▲1 | 17 | 15 | 8 | 2 | 20 |
| Austin | 14 | New | 16 | 14 | 18 | 5 | 2 |
| Bangalore | 15 | ▲4 | 10 | 6 | 20 | 17 | 12 |
| Sydney | 16 | ▼4 | 20 | 16 | 17 | 6 | 10 |
| Toronto | 17 | ▼9 | 14 | 18 | 14 | 15 | 18 |
| Vancouver | 18 | ▼9 | 18 | 19 | 15 | 14 | 11 |
| Amsterdam | 19 | New | 15 | 20 | 10 | 18 | 16 |
| Montreal | 20 | New | 19 | 17 | 16 | 13 | 17 |

*Source: Compass (2015)*

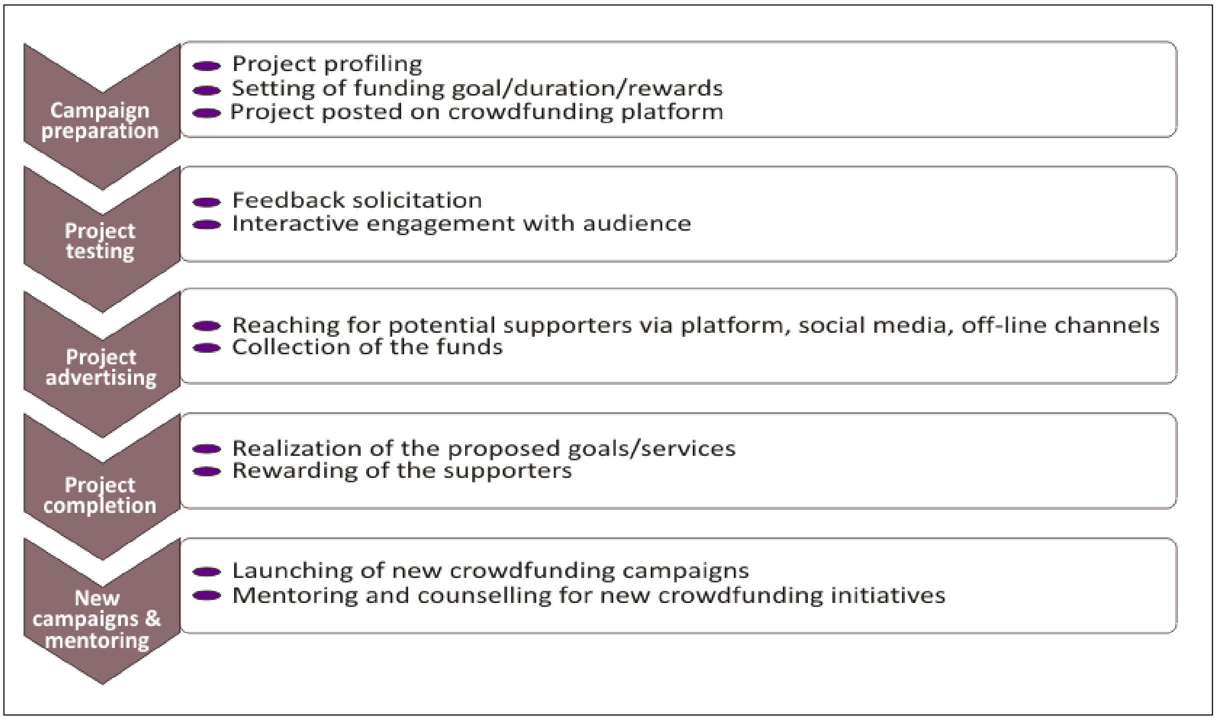
(2) Venture capital, financing of innovation and crowdfunding

One of the long debated issues in financing of innovation is who is best suited for it. For Shumpeter (1943) it is large corporations, for Gompers and Lerner (2001) it is venture capital (VC) and for Mazzucato (2013), it is the state or government. Another candidate that has emerged is crowdfunding – which is basically the collective efforts of individuals who network and pool their money via (usually) the Internet to support innovative projects. VC and crowdfunding have now found traction as two important sources of financing. The contribution of VC to financing innovation is now very much doubted for essentially two broad reasons. First, much of what goes as VC (defined as equity and value-added support to technology-based ventures when they are in the early stage of their existence) is actually private equity that comes at much later stages and that too without the value-added support. As stated earlier, authors like Mazzucato (2013) have shown that much of what is financed by venture capitalists can ultimately be traced to governmental funding of these VC funds. Second, policy-makers typically interpret positive relations between VC investments and innovations as evidence that VC investments stimulate innovation (VC-first hypothesis). This interpretation is, however, one-sided because there may be a reverse causality that innovations induce VC investments (innovation-first hypothesis) – an arrival of new technology increases demand for VC. Hirukawa and Ueda (2011) analyse this causality issue of VC and innovation in the United

States' manufacturing industry, using both total factor productivity growth and patent counts as measures of innovation. They found that, consistent with the innovation-first hypothesis, total factor productivity growth is often positively and significantly related with future VC investment. And they could unearth little evidence that supports the VC-first hypothesis.

Crowdfunding, on the contrary, is fast emerging as an important source of finance for innovative start-ups. It is defined as an open call over the Internet for financial resources in the form of a monetary donation, sometimes in exchange for a future product, service or reward (Gerber, Hui and Kuo 2011). The life cycle of a crowdfunding campaign is outlined in Figure 17.

**Figure 17: Life cycle of a crowdfunding campaign**




*Source: Cordova, Dolci and Gianfrate (2015), p. 247*

The main advantage of crowdfunding is that crowdfunding platforms give the possibility to every person who owns a potentially valuable idea to test its market value, which implies that more innovation is possibly brought into the market with the potential being or becoming the new frontier. Second, crowdfunding projects can be launched with very little upfront costs. A third advantage is the possibility to produce positive spillovers to the members of a platform, as it could bring together a number of entrepreneurs with, say, complementary ideas. Finally, the format of crowdfunding platforms helps reduce asymmetric information flow between investors and founders, eventually leading to the financing of the most innovative projects and thereby to more efficient allocation of resources.

According to industry estimates in 2012, there were 700 crowdfunding platforms worldwide, of which India had 6, China had 4, Japan had 3, Australia had 12 and New Zealand had 3. Governments such as in the United States and the European Union have started promoting this way of financing innovative start-ups.

***Conditions under which policy instruments are effective***

Mani (2002) had demonstrated through a series of country case studies that financial instruments to promote innovations are effective only when certain conditions – what may be termed as sufficient conditions – are met. The most important of these conditions are the availability and quality of scientists and engineers. For instance, South Africa has some of the most attractive financial schemes, research grants and tax incentives to perform R&D. But the density of R&D researchers is very low in that country. Consequently, the GERD-to-GDP ratio has not shown any increase over the years. Similar is the case of India as well. Although having the world's most generous R&D tax incentive scheme, India's GERD-to-GDP ratio has not shown any increase over the last several years. This is because, as seen earlier, the density of scientists and engineers engaged in R&D is one of the lowest. Other examples are the cases of Malaysia and Singapore. Both the countries have similar innovation policy instruments, but the GERD-to-GDP ratio of Singapore is much higher than that of Malaysia. Also, when Malaysia increased its density of scientists and engineers, its GERD-to-GDP ratio increased too. See Table 18 for the correlation between increasing GERD-to-GDP ratio and density of scientists and engineers in Singapore.

Increasing the density of scientists and engineers will have to be tackled from the both the supply and demand side of the spectrum. Increasing the enrolment, especially at the tertiary level, in science and engineering subjects can increase the supply of scientists and engineers. In most countries this is, relatively speaking, easily done by increasing the seats that are available for science and engineering subjects. Unfortunately, this increase is very often done at the cost of quality, with the result that the students who are graduating from these institutions are hardly suited or employable. Supply of quality scientists and engineers are adversely affected also by the migration of people with high skills, which seems to have increased significantly during the period of globalization. In democracies, high-skills migration is not stoppable and the best policy response is encouraging reverse migration or having policy instruments to brain-gain by tapping the diaspora network. The demand side of the story is even more complicated, as the demand for science and engineering careers are limited by their relatively less attractive incentive schemes (both financial compensation and possibility for career advancement) compared with, say, business management type of courses. Thus, it is not uncommon to find students from the top engineering schools like the Indian Institutes of Technology to go for post-graduate degrees in business management and then disappearing from the core human resource in science and technology. The ideal policy response to this is to incentivise science and engineering as a career choice.

**Logical sequencing of innovation policy instruments**

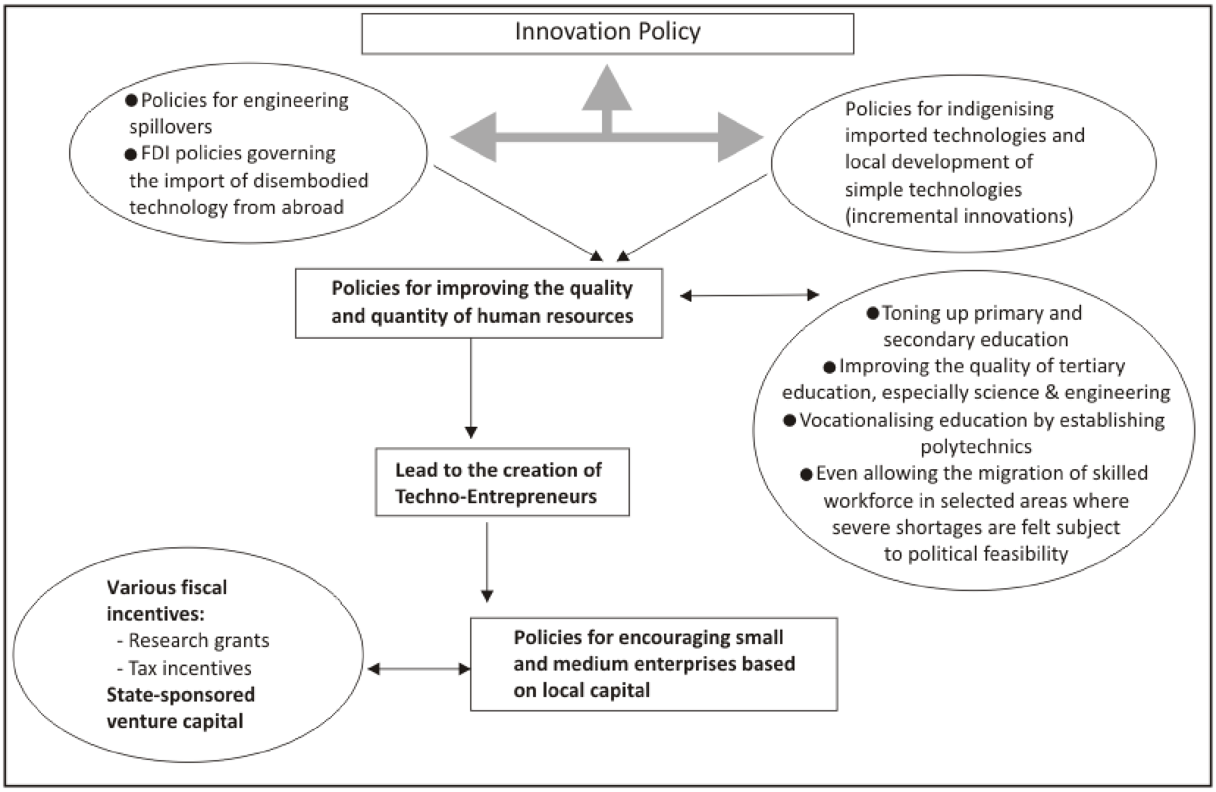
It is ideal if the policy instruments are sequenced even though innovation is not always a linear process. One model that has been successfully tried out is the Singapore model. Broadly, the innovation policy of the country has followed the sequencing that is outlined in Figure 18. The ultimate goal of Singapore's innovation policy was to enhance local development of technology through the medium of technology-based SMEs. The key to this was the creation of a pool of technically trained personnel who would emerge as techno-entrepreneurs as well as skilled workers in other firms. At the same time, the state encouraged positive spillovers from foreign companies operating in the country through a variety of instruments such as the Local Industry Upgrading Programme (LIUP). Fiscal incentives such as grants and tax incentives were put into operation only after a critical mass of this technically trained human resource was developed. In short, the country placed much emphasis on human resources development in the earlier years and subsequently on fiscal measures.

**Table 18: Trends in research intensity and density of R&D personnel in Singapore and Malaysia**

| Singapore Year | GERD to GDP (%) | Density of S&E per 10, 000 labour force | Malaysia Year | GERD to GDP (%) | Density of S&E per 10, 000 labour force |
|---|---|---|---|---|---|
| 1990 | 0.81 | 27.70 | 2000 | 0.50 | 15.60 |
| 1991 | 0.96 | 31.20 | 2002 | 0.69 | 18.00 |
| 1992 | 1.12 | 37.20 | 2004 | 0.63 | 21.30 |
| 1993 | 1.02 | 37.60 | 2006 | 0.64 | 17.90 |
| 1994 | 1.04 | 38.50 | 2008 | 0.79 | 28.50 |
| 1995 | 1.10 | 47.70 | 2009 | 1.01 | 47.10 |
| 1996 | 1.32 | 50.10 | 2010 | 1.07 | 59.40 |
| 1997 | 1.42 | 53.40 | 2011 | 1.07 | 58.07 |
| 1998 | 1.74 | 57.80 | 2012 | - | 57.45 |
| 1999 | 1.82 | 62.60 | | | |
| 2000 | 1.82 | 66.10 | | | |
| 2001 | 2.02 | 69.90 | | | |
| 2002 | 20.7 | 67.50 | | | |
| 2003 | 2.03 | 73.80 | | | |
| 2004 | 2.10 | 80.90 | | | |
| 2005 | 2.16 | 90.10 | | | |
| 2006 | 2.13 | 87.40 | | | |
| 2007 | 2.34 | 90.40 | | | |
| 2008 | 2.62 | 87.60 | | | |
| 2009 | 2.16 | 87.80 | | | |
| 2010 | 2.01 | 90.20 | | | |
| 2011 | 2.16 | 91.30 | | | |
| 2012 | 2.02 | 89.60 | | | |
| 2013 | 2.03 | 92.80 | | | |

*Source: Agency for Science, Technology and Research (2014)*

**Figure 18: The Singapore model of sequencing of innovation policy**




*Source: Mani (2002), p. 141*

## Step 5: Evaluating Effectiveness of Policy Instruments and M662aking Mid-Course Correction Using Indicators

Indicators can be used to monitor public spending on science, technology and innovation (STI) (Gault 2010). There are four questions that may be answered by using the indicators that we discussed in Step 3. The four questions are:

- How much does the government spend on STI?
- Where does it spend (geography and industry)?
- Why does it spend (socio economic objectives)?
- What does the government get for spending this money?

The last question requires a systems approach to get a meaningful answer. The gold standard in this field is a biennial evaluation of STI policies and outcomes along the four questions stated above conducted by NSB of the United States. The results of this exercise are published in a biennial document called the Science and Engineering Indicators.

Evaluation consists of three separate, but connected exercises: monitoring; benchmarking; and the evaluation itself. We will now discuss each of these steps briefly.

**Monitoring:** This essentially requires finding answers to the four questions by analysing the indicators. NSB's Science and Engineering Indicators, for instance, monitors the amount spent on innovative activity by the United States and compares it with other countries. Furthermore, it finds out the share of industries and regions in the total R&D expenditure so that one can form some opinion about industry and regional concentration in innovative activity. Indicators also help us find out if resources are devoted to technologies that improve educational and health outcomes. In addition, it can also help us find out if there are enough resources devoted to sustainable energy technologies (green energy).

**Benchmarking:** Here the approach is to agree upon the set of indicators and then select another NIS that may be in other respects comparable but is performing better according to a set of performance criteria. The values of the set of indicators for the comparable system become the targets. The advantage of this approach is that it includes a dynamic element as the comparator system may react quite differently to economic shocks such as the recent global financial crisis of 2008.

**Evaluation:** This concerns the effective and efficient allocation of resources in order to achieve a set of objectives. To be of use, it has to be done at the level of a specific programme or project, for instance, a project to develop nanotechnology. Methods of evaluation can be quantitative (bibliometric analysis, number of patents granted, new jobs created, turnover resulting from new products, etc.) or qualitative (such as per review). Examples of this include the STIP Reviews of UNCTAD and Country Reviews of Innovation Policy by OECD for both member and non-member countries.

### Critical Elements in the NIS

The most critical element in the NIS is the interaction between various actors. The quality of these interactions will vary from one NIS to another depending, of course, on the coordinating role the governments play. While there is nothing like an optimal level of interaction, there are best practices. For instance, the NISs of Japan, the Republic of Korea and Taiwan Province of China are universally acclaimed to be among the best. The fact that these countries are also the most innovative among the Asian countries, and even globally, confirms this line of reasoning. Hence, the most critical element is the quality of government coordination of various actors within the system especially the higher education and business enterprise sectors. In most countries of the Asia-Pacific region, the one area where discordance between the actors is most felt is between the higher education sector and business enterprises. The manifestation of this so-called systemic failure is the lack of supply of sufficient number of scientists and engineers who may contribute to innovative activity. Countries such as Singapore and Malaysia, which have corrected this imbalance, have been able to move forward in terms of innovative activity. So, the first critical element is the identification of this systemic failure. The second one, logically speaking, is the design of policy instruments to correct for these systemic failures. Success involves identifying the right policy instrument to correct for the specific systemic failure identified. Third critical element is the monitoring of the chosen policy instrument through its implementation. The fourth element is analysing its effectiveness in dealing with the identified systemic failure. All these require the services of an epistemic community, which must be assembled from both national and international experts. A fifth critical factor is the reduction of the influence of politics while defining policy instruments. For instance, while making a tax incentive generous, governments must have a clear idea of the costs in terms of corporate income tax lost and the benefits in terms of increased R&D. The sixth element is ensuring that increased innovative activity does not result in increased income inequality. This is the most important challenge facing countries especially in the Asia-Pacific region.

# Chapter 3: Conclusions

In this manual, we are primarily concerned with adopting the NIS framework for achieving the innovation and technology goals in the SDGs in the specific context of developing countries of Asia. Adoption of an NIS framework impacts on both local development of technology and absorption of imported technology. The implementation of an NIS strategy was seen in terms of five logically sequenced steps. The first step is the identification of the core of an innovation system. The core is defined as that actor that performs much of the innovative activity. Successful countries in Asia such as Japan, the Republic of Korea and, lately, the People's Republic of China have managed to shift the core of their respective NISs from state to business enterprises. Once the core is at business enterprises, the probability of conversion of research results to products and services that can be commercialised is increased manifold.

Once the core is identified, we need to find out what goes on within the core in terms of innovative activity and the nature and direction of interaction of the core with rest of the system. A very convenient way to do this is to conduct an innovation survey of the type done in the Community Innovation Surveys in Europe. Such a survey will help us identify the firms that have introduced not just product and process innovations but also marketing and organisational ones. Furthermore, it maps out the routes through which a business enterprise innovates and identifies specifically those non-R&D routes. It also has data on the source of information on innovation, which essentially gives firm-wise information on interaction with the other actors in the NIS. The survey also throws light on barriers to innovation and the effect of innovation on the firms' performance. In short, innovation surveys present us with a comprehensive picture of a nation's innovation system.

The third step would be to use a collection of input and output indicators to measure the performance of the NIS. The indicators that are most often used are R&D expenditure and patents. Needless to add, these indicators are relevant only for a country where the industry is composed largely of medium and large firms in the organised sector. For the rest, and especially for the small and medium sector, the non-R&D indicators (such as the sum of acquisition of capital goods, expenditure on training, purchase of designs and software, etc.) are more meaningful. Here, we also considered innovation indicators that are relevant for new and emerging technologies and also that denoting gender mainstreaming. An upward movement in these indicators is usually interpreted as an improvement in the health of the NIS.

Once the health of the NIS is assessed, the next step would be to design new innovation policy instruments or to evaluate existing ones. A range of instruments that are publicly provided but privately executed was considered. The fifth and final step involves monitoring, benchmarking and evaluating these policy instruments that not only innovations per se are increased but that also results in the release and diffusion of environmentally sound technologies that make the whole process of technological catching up more sustainable. Ensuring that the fruits of innovation are shared by everyone is another important perquisite for a sustainable development of countries in the Asia-Pacific region and indeed elsewhere.

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## Annex 1: National institutions in the Asia Pacific Region conducting research on STI issues

**People's Republic of China**
1. Chinese Academy of Science and Technology for Development (www.casted.org.cn/en)
2. Institute of Policy and Management, Chinese Academy of Science (english.ipm.cas.cn)
3. School of Public Policy and Management, Tsinghua University (www.sppm.tsinghua.edu.cn/english)

**India**
1. National Institute for Science Technology and Development Studies (www.nistads.res.in/index.php/en)
2. Centre for Studies in Science Policy, Jawaharlal Nehru University (www.jnu.ac.in/SSS/CSSP/info.htm)
3. Centre for Development Studies (cds.edu)

**Indonesia**
1. Indonesian Institute of Science (www.lipi.go.id)
2. University of Indonesia (www.ui.ac.id/en/#)
3. The Science and Technology Policy Asian Network – STEPAN (portal.unesco.org/geography/en/ev.php-URL_ID=9606&URL_DO=DO_TOPIC&URL_SECTION=201.html)

**Japan**
1. National Institute of Science and Technology Policy (www.nistep.go.jp/en)
2. National Graduate Institute for Policy Studies (www.grips.ac.jp/en)

**Republic of Korea**
1. Science and Technology Policy Institute (eng.stepi.re.kr/index_eng.jsp)
2. Korea Institute of Science and Technology (eng.kist.re.kr/kist_eng/main)

**Malaysia**
1. Academy of Sciences Malaysia (www.akademisains.gov.my)
2. Department of Development Studies, Faculty of Economics and Administration, University of Malaya (fep.um.edu.my/home)

**Singapore**
1. Agency for Science, Technology and Research (www.a-star.edu.sg)
2. Lee Kuan Yew School of Public Policy (lkyspp.nus.edu.sg)

**Taiwan, Province of China**

Science and Technology Policy Research Centre (www.stpi.narl.org.tw/welcome/index?locale=en)

**Viet Nam**

National Institute for Science and Technology Policy and Strategy Studies (nistpass.gov.vn:81)

*Note: In addition, there are units within universities and research institutes that conduct research on STI issues. However, these are, in most cases, those initiated by individual researchers.*

## Annex 2: A sample questionnaire for conducting a typical innovation survey

*(Based on the European Union Community Innovation Survey Harmonised Questionnaire of July 2012)*

This survey collects information on your enterprise's innovations and innovation activities during the three years 2014 to 2016

An innovation is the introduction of a new or significantly improved product, process, organizational method, or marketing method by your enterprise.

An innovation must have characteristics or intended uses that are new or which provide a significant improvement over what was previously used or sold by your enterprise. However, an innovation can fail or take time to prove itself.

An innovation need only be new or significantly improved for your enterprise. It could have been originally developed or used by other enterprises.

Sections 2 to 7 only refer to product and process innovations. Organizational and marketing innovations are covered in sections 8 and 9.

Please complete **all** questions, unless otherwise instructed.

**Person we should contact if there are any queries regarding the form:**

Name:

Job title:

Organisation:

Phone:

Fax:

E-mail:

### 1. General information about the enterprise

Name of enterprise:

Address: Postal code:

Main activity:

**1.1 In 2016, was your enterprise part of an enterprise group?** (A group consists of two or more legally defined enterprises under common ownership. Each enterprise in the group can serve different markets, as with national or regional subsidiaries, or serve different product markets. The head office is also part of an enterprise group.)

Yes In which country is the head office of your group located?

No

**If your enterprise is part of an enterprise group:** Please answer all further questions about your enterprise only for the enterprise for which you are responsible in [your country]. Exclude all subsidiaries or parent enterprises.

**1.2 During the three years 2014 to 2016 did your enterprise:**

| | | |
|---|---|---|
| Merge with or take over another enterprise? | **Yes** *1* | **No** *0* |
| Sell, close or outsource some of the tasks or functions of your enterprise? | **Yes** *1* | **No** *0* |
| Establish new subsidiaries in [your country] or in other Asian countries? | **Yes** *1* | **No** *0* |
| Establish new subsidiaries outside Asia? | **Yes** *1* | **No** *0* |

**1.3 In which geographic markets did your enterprise sell goods and/or services during the three years 2014 to 2016?**

| | | |
|---|---|---|
| A. Local / regional within [your country] | **Yes** *1* | **No** *0* |
| B. National (other regions of [your country]) | **Yes** *1* | **No** *0* |
| C. Other Asian countries | **Yes** *1* | **No** *0* |
| D. All other countries | **Yes** *1* | **No** *0* |

**Which of these geographic areas was your largest market in terms of turnover during the three years 2014- to 2016?** (Give corresponding letter)

## 2. Product (good or service) innovation

A product innovation is the market introduction of a **new** or **significantly** improved **good or service** with respect to its capabilities, user friendliness, components or sub-systems.

Product innovations (new or improved) **must be new to your enterprise**, but they **do not need to be new to your market**.

Product innovations could have been originally developed by your enterprise or by other enterprises or institutions.

A **good** is usually a tangible object such as a smartphone, furniture, or packaged software, but downloadable software, music and film are also goods. A **service** is usually intangible, such as retailing, insurance, educational courses, air travel, consulting, etc.

**2.1 During the three years 2014 to 2016, did your enterprise introduce:**

| | | |
|---|---|---|
| **Goods innovations:** New or significantly improved goods (exclude the simple resale of new goods and changes of a solely aesthetic nature) | **Yes** *1* | **No** *0* |
| **Service innovations**: New or significantly improved services | **Yes** *1* | **No** *0* |

**[If no to all options, go to section 3. Otherwise go to question 2.2]**

**2.2 Who developed these product innovations?** *(Tick all that apply)*

| | Goods innovations | Service innovations |
|---|---|---|
| Your enterprise by itself | | |
| Your enterprise together with other enterprises/institutions* | | |
| Your enterprise by adapting or modifying goods or services originally developed by other enterprises/institutions* | | |
| Other enterprises/institutions* | | |

**: Include independent enterprises plus other parts of your enterprise group (subsidiaries, sister enterprises, head office, etc.). Institutions include universities, research institutes, non-profits, etc.*

**2.3 Were any of your product innovations (goods or services) during the three years 2014 to 2016:**

| | | Yes *1* | No *0* |
|---|---|---|---|
| **New to your market?** | Your enterprise introduced a new or significantly improved product onto your market before your competitors (it may have already been available in other markets) | | |
| **Only new to your firm?** | Your enterprise introduced a new or significantly improved product that was already available from your competitors in your market | | |

**Using the definitions above, please give the percentage of your total turnover in 2012 from:**

| | | |
|---|---|---|
| New or significantly improved products introduced during the three years 2014 to 2016 that were **new to your market** | | **%** |
| New or significantly improved products introduced during the three years 2014 to 2016 that were **only new to your firm** | | **%** |
| Products that were **unchanged or only marginally modified** during the three years 2014 to 2016 (include the resale of new products purchased from other enterprises) | | % |
| Total turnover in 2016 | 1 0 0 | % |

**2.4 To the best of your knowledge, were any of your product innovations during the three years 2014 to 2016:**

| | Yes *1* | No *0* | Don't know *2* |
|---|---|---|---|
| A first in [your country] | | | |
| A first in Asia | | | |
| A world first | | | |

**[If no world-first product innovations go to Section 3, otherwise go to question 2.5]**

**2.5 What percent of your total turnover in 2016 was from world first product innovations introduced between 2014 and 2016?** *(This should be a subset of your new-to-market turnover share in question 2.3 above)*

| | |
|---|---|
| 0% to less than 1% | *1* |
| 1% to less than 5% | *2* |
| 5% to less than 10% | *3* |
| 10% to less than 25% | *4* |
| 25% or more | *5* |
| Don't know | *6* |

## 3. Process Innovation

A process innovation is the implementation of a **new** or **significantly** improved production process, distribution method, or supporting activity.

Process innovations **must be new to your enterprise**, but they **do not need to be new to your market.**

The innovation could have been originally developed by your enterprise or by other enterprises or institutions. Exclude purely organisational innovations – these are covered in section 8.

**3.1 During the three years 2014 to 2016, did your enterprise introduce?**

| | **Yes** | **No** |
|---|---|---|
| | *1* | *0* |
| New or significantly improved methods of manufacturing or producing goods or services | | |
| New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services | | |
| New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing | | |

**[If no to all options, go to section 4. Otherwise go to question 3.2]**

**3.2 Who developed these process innovations?**

*Tick all that apply*

Your enterprise by itself

Your enterprise together with other enterprises or institutions*

Your enterprise by adapting or modifying processes originally developed by other enterprises or institutions*

Other enterprises or institutions*

**3.3 Were any of your process innovations introduced during the three years 2014 to 2016 new to your market?**

Yes *1*

No *0*

Do not know *2*

## 4. Ongoing or abandoned innovation activities for product and process innovations

Innovation activities include the acquisition of machinery, equipment, buildings, software, and licenses; engineering and development work, design, training, and marketing when they are specifically undertaken to develop and/or implement a product or process innovation. Also include all types of R&D activities.

*: *Include independent enterprises plus other parts of your enterprise group (subsidiaries, sister enterprises, head office, etc). Institutions include universities, research institutes, non-profits, etc.*

**4.1 During the three years 2014 to 2016, did your enterprise have any innovation activities that did not result in a product or process innovation because the activities were:**

| | Yes | No |
|---|---|---|
| | *1* | *0* |
| Abandoned or suspended before completion | | |
| Still on-going at the end of the 2014 | | |

**[If your enterprise had no product or process innovations or innovation activity during the three years 2014 to 2016 (no to all options in questions 2.1, 3.1, and 4.1), go to section 8. Otherwise go to Section 5.]**

## 5. Activities and expenditures for product and process innovations

**5.1 During the three years 2014 to 2016, did your enterprise engage in the following innovation activities:**

| | | Yes | No |
|---|---|---|---|
| | | *1* | *0* |
| **In-house R&D** | Research and development activities undertaken by your enterprise to create new knowledge or to solve scientific or technical problems (include software development in-house that meets this requirement) | | |
| | If yes, did your enterprise perform R&D during the three years 2010 to 2012: | | |
| | Continuously (your enterprise has permanent R&D staff in-house) | *1* | |
| | Occasionally (as needed only) | *2* | |
| **External R&D** | R&D that your enterprise has contracted out to other enterprises (including other enterprises in your group) or to public or private research organisations | | |
| **Acquisition of machinery, equipment, software & buildings** | Acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes | | |
| **Acquisition of existing knowledge from other enterprises or organisations** | Acquisition of existing know-how, copyrighted works, patented and non-patented inventions, etc. from other enterprises or organisations for the development of new or significantly improved products and processes | | |
| **Training for innovative activities** | In-house or contracted out training for your personnel specifically for the development and/or introduction of new or significantly improved products and processes | | |
| **Market introduction of innovations** | In-house or contracted out activities for the market introduction of your new or significantly improved goods or services, including market research and launch advertising | | |

| | | Yes | No |
|---|---|---|---|
| | | *1* | *0* |
| **Design** | In-house or contracted out activities to design or alter the shape or appearance of goods or services | | |
| **Other** | Other in-house or contracted out activities to implement new or significantly improved products and processes such as feasibility studies, testing, tooling up, industrial engineering, etc. | | |

**5.2 How much did your enterprise spend on each of the following innovation activities in 2016 only?** Innovation activities are defined in question 5.1 above. Include current expenditures (including labour costs, contracted-out activities, and other related costs) as well as capital expenditures on buildings and equipment.[7]

*Please fill in '0' if your enterprise had no expenditures for an activity in 2016*
*With a lack of precise accounting data please use estimates*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **In-house R&D** (Include current expenditures including labour costs and capital expenditures on buildings and equipment specifically for R&D) | | | | | | | | |
| **External R&D** | | | | | | | | |
| **Acquisition of machinery, equipment, software & buildings** (Exclude expenditures on these items that are for R&D) | | | | | | | | |
| **Acquisition of existing knowledge from other enterprises or organisations** | | | | | | | | |
| **All other innovation activities including design, training, marketing, and other relevant activities** | | | | | | | | |
| **Total expenditures on innovation activities** (Sum of expenditures for all types of innovation activities) | | | | | | | | |

**5.3 During the three years 2014 to 2016, did your enterprise receive any public financial support for innovation activities from the following levels of government?** Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude research and other innovation activities conducted entirely for the public sector* under contract.

| | Yes | No |
|---|---|---|
| | ***1*** | ***0*** |
| Local or regional authorities | | |
| Central government (including central government agencies or ministries) | | |
| ASEAN | | |

7 *Give expenditure data in 000's of national currency units to eight digits.*

* *The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.*

## 6. Sources of information and co-operation for product and process innovation

**6.1 During the three years 2010 to 2012, how important to your enterprise's innovation activities were each of the following information sources?** Include information sources that provided information for new innovation projects or contributed to the completion of existing projects.

| Information source | | Degree of importance<br>*Tick 'not used' if no information was obtained from a source*<br>High *3* | Medium *2* | Low *1* | Not used *0* |
|---|---|---|---|---|---|
| **Internal** | Within your enterprise or enterprise group | | | | |
| | Suppliers of equipment, materials, components, or software | | | | |
| | Clients or customers from the private sector | | | | |
| | Clients or customers from the public sector* | | | | |
| **Market sources** | Competitors or other enterprises in your industry | | | | |
| | Consultants and commercial labs | | | | |
| **Education & research institutes** | Universities or other higher education institutions | | | | |
| | Government, public or private research institutes | | | | |
| **Other sources** | Conferences, trade fairs, exhibitions | | | | |
| | Scientific journals and trade/technical publications | | | | |
| | Professional and industry associations | | | | |

**6.2 During the three years 2014 to 2016, did your enterprise co-operate on any of your innovation activities with other enterprises or institutions?** Innovation co-operation is active participation with other enterprises or institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.

Yes

No [**Please go to question 7.1]**

**6.3 Please indicate the type of innovation co-operation partner by location**

*(Tick all that apply)*

| Type of co-operation partner | [Your country] | Other Asia** | United States | China or India | All other countries |
|---|---|---|---|---|---|
| A. Other enterprises within your enterprise group | | | | | |
| B. Suppliers of equipment, materials, components, or software | | | | | |
| C. Clients or customers from the private sector | | | | | |
| D. Clients or customers from the public sector* | | | | | |
| E. Competitors or other enterprises in your sector | | | | | |
| F. Consultants and commercial labs | | | | | |
| G. Universities or other higher education institutions | | | | | |
| H. Government, public or private research institutes | | | | | |

**The public sector includes government owned organizations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.*

**6.4 Which type of co-operation partner did you find the most valuable for your enterprise's innovation activities? (Give corresponding letter)**

## 7. Competitiveness of your enterprise's product and process innovations

**7.1 How effective were the following methods for maintaining or increasing the competitiveness of product and process innovations introduced during 2014 to 2016?**

| | Degree of effectiveness | | | |
|---|---|---|---|---|
| | High | Medium | Low | Not used |
| | *3* | *2* | *1* | *0* |
| Patents | | | | |
| Design registration | | | | |
| Copyright | | | | |
| Trademarks | | | | |
| Lead time advantages | | | | |
| Complexity of goods or services | | | | |
| Secrecy (include non-disclosure agreements) | | | | |

Note: Countries that provide utility patents should include this as a sub-question after patents.

## 8. Organizational Innovation

An organizational innovation is a new organizational method in your enterprise's business practices (including knowledge management), workplace organization or external relations that has not been previously used by your enterprise.

It must be the result of strategic decisions taken by management. Exclude mergers or acquisitions, even if for the first time.

**8.1 During the three years 2014 to 2016, did your enterprise introduce:**

| | Yes | No |
|---|---|---|
| | *1* | *0* |
| New business practices for organising procedures (i.e. supply chain management, business re-engineering, knowledge management, lean production, quality management, etc.) | | |
| New methods of organizing work responsibilities and decision making (i.e. first use of a new system of employee responsibilities, team work, decentralisation, integration or de-integration of departments, education/training systems, etc.) | | |
| New methods of organising external relations with other firms or public institutions (i.e. first use of alliances, partnerships, outsourcing or sub-contracting, etc.) | | |

## 9. Marketing innovation

A marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from your enterprise's existing marketing methods and which has not been used before.

It requires significant changes in product design or packaging, product placement, product promotion or pricing. Exclude seasonal, regular and other routine changes in marketing methods.

**9.1 During the three years 2014 to 2016, did your enterprise introduce:**

| | Yes *1* | No *0* |
|---|---|---|
| Significant changes to the aesthetic design or packaging of a good or service (exclude changes that alter the product's functional or user characteristics – these are product innovations) | | |
| New media or techniques for product promotion (i.e. the first time use of a new advertising media, a new brand image, introduction of loyalty cards, etc.) | | |
| New methods for product placement or sales channels (i.e. first time use of franchising or distribution licenses, direct selling, exclusive retailing, new concepts for product presentation, etc.) | | |
| New methods of pricing goods or services (i.e. first time use of variable pricing by demand, discount systems, etc.) | | |

## 10. Public sector procurement and innovation

**10.1 During the three years 2014 to 2016, did your enterprise have any procurement contracts to provide goods or services for:**

| | Yes *1* | No *0* |
|---|---|---|
| Domestic public sector organisations* | | |
| Foreign public sector organisations* | | |

**[If no to both options go to section 11. Otherwise go to question 10.2]**

**10.2 Did your enterprise undertake any innovation activities as part of a procurement contract to provide goods or services to a public sector organisation?** *(Include activities for product, process, organisational and marketing innovations)*

*(If your enterprise had several procurement contracts, tick all that apply)*

Yes and innovation required as part of the contract

Yes but innovation *not* required as part of the contract

No

## 11. Strategies and obstacles for reaching your enterprise's goals

**11.1 During the three years 2010 to 2012, how important were each of the following goals for your enterprise?** (It does not matter if your enterprise was able to attain these goals)

| | Degree of Importance | | | |
|---|---|---|---|---|
| | **High** *3* | **Medium** *2* | **Low** *1* | **Not relevant** *0* |
| Increase turnover | | | | |
| Increase market share | | | | |
| Decrease costs | | | | |
| Increase profit margins | | | | |

**11.2 During 2014 to 2016, how important were each of the following strategies for reaching your enterprise's goals?**

| | Degree of Importance | | | |
|---|---|---|---|---|
| | High | Medium | Low | Not relevant |
| | *3* | *2* | *1* | *0* |
| Developing new markets within Asia | | | | |
| Developing new markets outside Asia | | | | |
| Reducing in-house costs of operation | | | | |
| Reducing costs of purchased materials, components or services | | | | |
| Introducing new or significantly improved goods or services | | | | |
| Intensifying or improving the marketing of goods or services | | | | |
| Increasing flexibility / responsiveness of your organisation | | | | |
| Building alliances with other enterprises or institutions | | | | |

**11.3 During 2010 to 2012, how important were the following factors as obstacles to meeting your enterprise's goals?**

| | Degree of Importance | | | |
|---|---|---|---|---|
| | High | Medium | Low | Not relevant |
| | *3* | *2* | *1* | *0* |
| Strong price competition | | | | |
| Strong competition on product quality, reputation or brand | | | | |
| Lack of demand | | | | |
| Innovations by competitors | | | | |
| Dominant market share held by competitors | | | | |
| Lack of qualified personnel | | | | |
| Lack of adequate finance | | | | |
| High cost of access to new markets | | | | |
| High cost of meeting government regulations or legal requirements | | | | |

## 12. Basic economic information on your enterprise

**12.1 What was your enterprise's total turnover for 2014 and 2016?**[8]
Turnover is defined as the market sales of goods and services (Include all taxes except VAT[9])

| 2014 | 2016 |
|---|---|
| | |

*[8] Give turnover in '000 of national currency units. Leave space for up to nine digits.*
*[9] For Credit institutions: Interests receivable and similar income; for Insurance services give gross premiums written.*

**12.2 What was your enterprise's average number of employees in 2014 and 2016?**[10]

| 2014 | 2016 |
|---|---|
| | |

**12.3 A p p r o x i m a t e l y what per cent of your enterprise's employees in 2016 had a tertiary degree?**[11]

| | |
|---|---|
| 0% | *0* |
| 1% to 4% | *1* |
| 5% to 9% | *2* |
| 10% to 24% | *3* |
| 25% to 49% | *4* |
| 50% to 74% | *5* |
| 75% to 100% | *6* |

[10] If administrative data are used and the annual average is not available, give results for the end of each year. Leave space for up to six digits for question 12.2.

[11] ISCED 2011 levels 5 to 8.