Research and Development (R&D) and Innovation Index

Preamble: Research and Development (R&D) and Innovation

Scientific research, experimental development and innovation are important factors in determining a country's success in building its own knowledge economy and society. Research and innovation serve as an engine for economic growth and sustainable development in both advanced and developing countries alike.[1]

Decision-makers in this domain require trustworthy indicators to benchmark and monitor their progress in establishing or maintaining a knowledge economy as well as to create effective innovation policies to keep pace with the rapid developments of the knowledge era. Analytical indicators of research and experimental development (R&D), as well as measures of science and technology (S&T) are the most widely used indicators to monitor and evaluate a country's national innovation system (NIS). The three international and regional organisations concerned with the development and assessment of these areas, as well as innovation policies and systems, are the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the Organisation for Economic Cooperation and Development (OECD) and the World Bank. They provide manuals, technical reports and policy papers that support the estimation of worldwide or country-specific statistics and indicators assessing progress towards establishing knowledge societies.[2]

In general, Arab countries face problems in applying international standards due to their specific socioeconomic, cultural and political contexts. Some of these problems that merit considerable attention are: (1) the heterogeneity of the Arab states in terms of their socio-economic structure and their systems for research and innovation; (2) the volatility and inconsistency of statistics due to the concentration of innovation activities in a limited number of productive sectors or in a small group of institutes; and (3) the concentration of the majority of R&D activities in institutions of higher education and public organisations, with an extremely limited or less important role for independent R&D units and the private sector.[3]

These dimensions and their associated challenges must be considered when developing an Arab index. Furthermore, a strong research base is needed in any systemic approach, incorporating dimensions of scientific research, development and innovation, while an appropriate enabling environment is also required to ensure their coherence and integrity.

Basic Concepts and Definitions

- Research and development comprise the creative work undertaken on a systematic basis in order to increase the stock of knowledge – including knowledge of people, culture and society – and the use of this stock of knowledge to devise new applications. R&D is broadly divided into three types: basic research, applied research and experimental development.[4] The first refers to the systematic work being done to acquire new knowledge of the underlying foundation of phenomena and observable facts, without targeting any specific application. Applied research, on the other hand, also represents original investigation undertaken in order to acquire new knowledge in a specific socioeconomic, cultural and political context, but is directed primarily towards a specific practical aim or objective. Finally, experimental development refers to systematic work drawing on existing knowledge gained from research and/or practical experience with the aim of producing new materials, products or devices, or installing new processes, systems and services. Policy- and decision-makers use R&D statistics as a key element in the formulation of government programmes and an important tool in their evaluation. Science and technology indicators may be regarded as proxies for indicators on R&D and innovation, as well as for other scientific and technological statistics.[5] Scientific and technological activities can be defined as systematic activities that are closely concerned with the generation, advancement,

dissemination and application of scientific and technical knowledge in all S&T fields, including the natural sciences, engineering and technology, medical and agricultural sciences, and the social sciences and humanities.

- Innovation is the creation of a new or a highly improved product (goods and services), process, marketing method or organisational model for business, the workplace or external relations. Based on this definition, four categories of innovation activity can be identified: product, process, marketing or organisational innovation.[6] Innovative activities are identified as scientific, technical, regulatory, financial or commercial steps that lead – or are intended to lead – to the implementation of innovations. Some innovative activities may not be innovative per se, or new, but are necessary for implementing innovations. Innovative activities necessarily include R&D not connected directly to developing a specific innovation. On the other hand, innovation should be applied; for example, new products should be introduced to markets, as should new processes and means of marketing. In addition, innovative activities can be described as comprising one important change, or a series of smaller incremental changes that lead, collectively, to a large change. Accordingly, it can be found in four separate types of innovation:[7]

  - Product innovation, introducing a new or noticeably improved product or service in relation to its properties or intended usages. This includes tangible improvements in technical specifications, components, materials, embedded software, ease of use or other functional properties;

  - Process innovation, implementing a process to increase quality, produce a new or significantly improved product and deliver it-perhaps employing a new or significantly improved method of delivery. Scientific innovations can be intended to reduce unit costs of production or delivery, increase quality, produce new or significantly improved products, or deliver them;

  - Marketing innovation, through the introduction of a new marketing method involving significant changes in product design, packaging, mobility, promotion or pricing (the five components of the marketing mix). Marketing innovations aim to better meet consumer needs through the opening of new markets to increase a company's sales;

  - Organisational innovation entails implementing a new organisational method in a company's business practices, or organizing its workplace or external relations. The ultimate goal is to develop a company's performance by reducing input, administrative or production process costs and improving the business climate.

R&D and Innovation Index Selection and Construction Methodology

The process of selecting indicators to construct the composite index for the R&D and innovation sector entailed a series of preparatory processes; in particular, it was necessary to revert to relevant databases and reports to check currently adopted indicators (inventory and description phase), and examine and analyse them to determine their type, conceptual–technical approaches and determinants (analysis and critiquing phase). This would act as a prelude to the actual construction of an "alternative" index, which would represent an essential appendage to the Arab Knowledge Index. The following is the outcome of these two phases of description and analysis.

Global Models for Measuring R&D and Innovation

A review of international reports and studies revealed that the R&D index enjoys a certain level of stability in terms of inputs, outputs and indicators of its performance. Review of scientific papers and statistical references

also shows that indicators of scientific research and development are available, to a large extent, through science, technology and R&D databases prepared by UNESCO. The variety of studies employed in measuring the innovation index indicates the multiplicity of approaches and methods used for the composition of the indicators required to estimate its inputs and outputs.

R&D and Innovation Index

Most manuals and analytical studies agree that the R&D index should be divided into a set of indicators specific to its inputs and another set reflecting its outputs. That is to say, R&D and innovation are dealt with as a productivity process requiring a set of inputs and outputs, summed up in the following categories:

- Expenditure on R&D and its share of gross domestic product (GDP), government expenditure or national income;
- Researchers' share of total expenditure on R&D;
- The number of workers in the field of R&D, divided into three categories: scientific researchers, technicians and professionals, and providers of support services;
- The number of researchers per million inhabitants;
- The number of researchers in relation to the total labour force;
- Sources of funding for R&D;
- Expenditure on R&D with quality (basic research, applied research and experimental development).

Outputs of the R&D process are determined by the following set of indicators:

- Scientific publication (quantity of scientific research published by the researcher, and the extent to which his work is cited [average]);
- Patent statistics (total number of patents submitted during a specific period, according to type);
- Imports and exports of high-tech products (proportion of high-tech imports to total imports).

Trends in Measuring the Innovation Composite Index

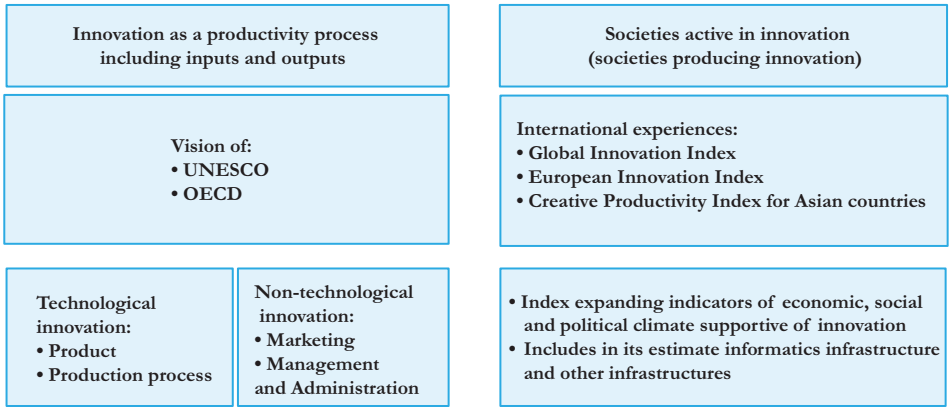
According to references in this area, there are four main approaches to measuring an innovation index, as shown in Figure 1:

UNESCO's Vision for Innovation

This vision adopts the definition of the Oslo Manual, developed by the Organisation for Economic Co-operation and Development

Figure 1:

Global Trends in Measuring Innovation Indices



(OECD). Innovation outputs are determined by the innovative goods and services produced by economic units and what they contribute in terms of achieving modern management and marketing methods. These outputs also assess the impact of innovative processes on economic and financial market performance, and evaluate projected obstacles to innovation activities in addition to indicators regarding intellectual property rights. Meanwhile, innovation inputs are measured in terms of innovative activities, institutional connecting factors that support innovation and the required expenditure to achieve innovative products, processes, marketing and regulatory frameworks. In analysing innovation inputs and outputs worldwide UNESCO, depends on statistical research and surveys conducted by participating countries in this field – i.e. through its vision the Organisation seeks to deal with innovation as a productivity process, unified in its inputs and outputs. By identifying these inputs and outputs, some of the environmental and infrastructural variables can be explored.

European Union (EU) Innovation Index[8]

Due to the reduced role of R&D indicators, the proposed hierarchical framework, and the manuals and indicators it utilises, have basically focused on activities geared toward innovation, with a view to devising means with which to support it; although the index document confirms that the statistical effort will focus on evaluating scientific R&D and innovation by aligning areas of weaknesses and the sources of strengths. The EU innovation index is divided into the following inputs and outputs:

- Innovation inputs include: 1) project activities including investments, institutional connections, entrepreneurship and patent applications; and 2) enablers including human resources (human capital), the scientific research system and financial support for innovation.
- Innovation outputs include: 1) economic impacts, including employment in knowledge-intensive services, medium and high-tech products, and knowledge-intensive industries with high added value; and 2) innovators that are productive small and medium-sized enterprises (SMEs) active in the field of innovative products and processes, and productive SMEs active in the field of marketing innovation and organisational capacity.

Thus, it is clear that the innovation composite index for the EU countries re-distributes inputs and outputs to the innovation process (as shown in the Oslo Manual for innovation and employed by UNESCO) and adds to it variables that support innovation and are specifically related to the economic and social climate and infrastructure (such as highly efficient human resources, education and information technology structure).

Global Innovation Index (GII)[9]

This Index, prepared by a number of advisory and educational institutions, includes a significant expansion in terms of measuring the accompanying climate and innovation-fostering environment. Despite the commitment to identifying innovation inputs and outputs, as is the case in previous visions and orientations, expansion in the institutional, political, economic and social climate as well as in infrastructure should be provided for in determining the success of the innovation process. The index proceeds from the basis that innovation necessarily requires an "innovative society", the components of which include:

- Innovation inputs, such as the political, legal and regulatory environment, business climate, human capital, scientific research and training, information and communication technology (ICT) infrastructure, natural infrastructure, environmental sustainability, and the complexity of markets (borrowing, investment, trade and competition) and business (labour, institutional connection and absorption of knowledge).
- Innovation outputs that include qualitative outputs (intangible assets,

innovative products and services, and direct creativity over the Internet) and knowledge and technological outputs (knowledge production, dissemination and impact).

The limited relative weight of research and development is noticeable in this indicator, based on the assumption that innovation is a phenomenon that often occurs outside the scope of R&D. This indicator also differs from those preceding it in terms of its introduction of the concept of an institutional framework including the rule of law, political stability and security, and the efficiency of the judicial system. Despite the innovative society's logical premise, the major expansion of the economic, social and political environments and infrastructure should be tested in some way to justify the unprecedented expansion in analytical and planning indicators.

The Asian Creative Productivity Index (CPI)[10]

This composite index seeks to analyse creative capabilities and technological and non-technological innovation for the Asian countries. The CPI's vision is based on the fact that the economies of many Asian countries suffer from declining returns on investment, capital and labour, and a reliance on cheap natural resources, all of which necessitate a re-evaluation of their development strategies. One of the main challenges facing most Asian countries in the third millennium is posed by the transition from an economy dependent on the use of available resources and export-supporting policies, to a more sustainable development model based on building human capital and developing modern technology and innovation.

This indicator is mainly intended to provide a flexible analytical tool to support decision-makers in regard to measuring the extent of progress in the area of creativity and innovation in 22 Asian countries, and comparing it to the achievements of both the United States and Finland in this field. Thus, the Asian CPI seeks to measure: the abilities of each country in terms of creativity and innovation; the extent of their scientific and technical development that contributes to the formulation of new and innovative ideas, visions, products and methods; and their efficiency in the use of production factors in industrial and service institutions (inputs to the production process) producing goods and services (outputs of the productivity process). At the methodological level, the CPI depends on modern growth theory and measures innovation in three dimensions – knowledge and competitive skills, dynamism of productive activities, and effective or appropriate institutional framework – so that every country receives a numerical estimate related to the inputs and outputs of the creativity and innovation process. It consists of 36 variables for inputs and 8 for outputs that are distributed across quantitative (25) and qualitative (9) variables. It should also be noted that the Asian CPI joins the Global Innovation Index (GII) in estimating the rates of innovation productivity performance or efficiency by dividing the sub-index of outputs by the sub-index of creativity inputs.

Data and Indicator Sources

Composite indicators and analytical manuals of R&D and innovation are formulated and disseminated globally through four international institutions: UNESCO, OECD, World Bank and the United Nations Development Programme (UNDP), as well as a number of educational, research and advisory institutions interested in the areas of scientific R&D and innovation at the regional and global levels. OECD has issued technical manuals for R&D (Frascati Manual), and innovation (Oslo Manual) that include specific guidelines, analytical methods and means of measurement.[11] It has also issued a number of reports and research studies that link R&D and innovation on the one hand, and sustainable development and knowledge economy on the other.[12] UNESCO participates in measuring innovation manuals through the Community Innovation Survey (CIS). The survey components of innovation inputs and outputs have been composed and standardised so that they can be utilised at the national level on a regular basis, in periods ranging from two to four years. The database of the UNESCO Institute for Statistics (UIS)

is the most important source of statistics and indicators relevant to R&D, innovation activities and composite manuals; while the World Bank provides indicators related to the knowledge economy and the role of innovation development.[13]

Analytical and Critical Reading of Currently Established Approaches

Undoubtedly, these different experiments are an important asset in monitoring and measuring the field of R&D and innovation, and constitute a rich resource that can help in generating alternative indicators through new intellectual insights and methodological tools. Therefore, a number of points should be discussed as basic starting points for directions adopted by the current work. Through the presented experiences and approaches, the following may be noted:

- Approaches to constructing the composite index draw on statistics and data that are often collected through specialised surveys. Despite the multiplicity of regional and international efforts to construct composite indicators for both R&D and innovation, the statistics concerning research, development, and science and technology are not sufficient to contribute to the development of a comprehensive index of the knowledge economy and its society. It is increasingly apparent that there is a need to examine these data in light of a conceptual framework that links them to other types of indicators and statistics that allow measurement of the impact on the economy and society in general. This link can be made under the innovation process, or in the context of a wider work, which not only includes related R&D, sciences and technology activities, but also the expenses of software, training and organisation.[14]

- The approach to designing and developing the composite index could be based on the full R&D cycle, with indicators arranged according to research stages, beginning with preliminary investigation and exploration, followed by basic and applied research and experimental development, and ending with developing a product, a process, a marketing method or a new – or significantly improved – regulatory plan. The second approach is based on the results of the R&D stages or the marketing mix consisting of four elements: product, price, place and promotion (the 4Ps). The R&D results are grouped into research papers, patents, models and products.

- The CPI combines both the Oslo Manual methodology in dealing with innovation as a production process that requires inputs and outputs, and the method employed by the Global Innovation Index that supports the trend towards building an innovative or creative community. Despite the CPI's importance, however, it is criticised for its dependence on equally weighted averages across all indicators. Its architects justify this dependence by citing the absence of sufficient theoretical and scientific background to determine the optimal allocation of proportional weights. While the results have reported that the classification of Asian countries has not been affected by the imposition of equal relative weights assigned for all indicators used in the synthesis of the CPI, this in no way precludes an interpretive judgement regarding the distribution of relative weights according to a coherent methodological framework serving the objectives of the composite index. The likelihood of some errors or deficiencies occurring in the specification process does not lessen the importance of determining the relative weighted average of the composite index variables through a number of technical transactions.

- Previous studies and efforts have sought to measure innovation and R&D either together or separately. However, separation of these two areas – in terms of their individual contributions to building modernity and knowledge societies – tends to ignore the fact that research and development are among the key inputs of the innovation process. Hence, it is necessary to formulate

a composite index that combines them in an integrated framework to support Arab knowledge production. Furthermore, constructing a composite or synthetic index including them together may reduce recurrences and statistical overlap among the measured indicators.

Presenting the R&D and Innovation Index

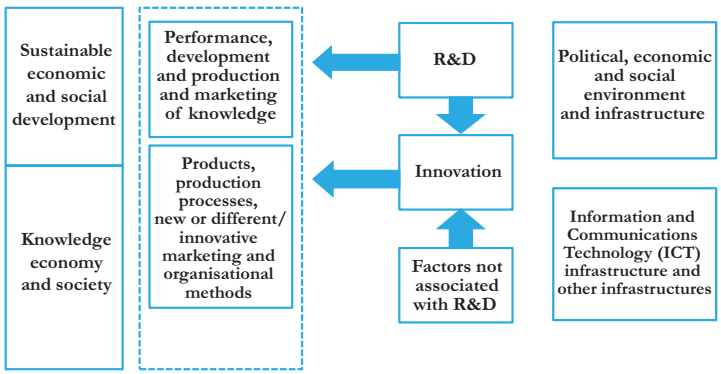
Vision for Constructing the Composite Index for the R&D and Innovation Sector

The research effort to construct a new composite index for R&D and innovation draws on previous visions and orientations, and attempts to develop them towards designing a composite index for knowledge that takes into account the Arab region's institutional, economic and social characteristics. The proposed index philosophy establishes that R&D and innovation both contribute effectively to producing knowledge, increasing the knowledge stock and using it to create new applications. It considers that the difference between them lies mainly in the level of development in knowledge outputs and their application on the one hand, and the community impact on sustainable economic and social development rates on the other. This orientation is in line with most of the strategic plans for scientific R&D on a global scale that accept the principle of a full R&D cycle. These plans also accept linking schematic and analytical indicators, measured in this area with scientific research stages that begin with basic and applied research and end in the development of a product, a productivity process or a new method in the context of innovative activities.

Based on the assessment of previous references and studies, and taking the objectives of the current project into account, the R&D and Innovation Index seeks to formulate a number of manuals, substrates and indicators that emphasise the role of R&D and the importance of innovation in the formation of the Arab Knowledge Index (AKI). The Index is also designed to take into account political, economic and social variables, as well as appropriate infrastructure, in efforts to move toward knowledge societies and economies in the third millennium. This means that the proposal submitted for measuring R&D and innovation distinguishes between scientific research or innovation as a productivity process including specific inputs and outputs, and the requirements for each to achieve an economic, social, political, institutional and cultural climate, and an IT and non-IT structure.

Figure 2:

Methodological Framework for the R&D and Innovation Index



In the composite index, this methodological choice divides R&D and innovation into two types of inputs. The first deals with the technical inputs of scientific R&D and innovation as a productive process that ends with providing a scientific research service to the community and avails new marketing and regulatory products and services within the framework of innovation for development. The second type focuses on economic, social and political variables, and infrastructure that contributes to the provision of scientific research services or innovation production. Accordingly, the Index must also specify the outputs that can be measured or assessed for both scientific research and innovation separately, considering their common dimensions. Figure 2 summarises the proposed methodological framework for the development of an R&D and Innovation Index.

Despite the relative stability of R&D input and output measurements, the development of a composite index for innovation has seen the inclusion of various methodological frameworks and sub-indices. While basic and applied research, experimental development and innovation generally represent the main sources for the creation and spread of knowledge, innovation is considered the driving force for economic and social growth and the main contributing factor in achieving sustainable development. Based on this concept, the prospective composite knowledge index will take into consideration the components of the full cycle of R&D and innovation and link them together, starting from the discovery of research ideas and conducting basic research to the production and implementation of creative results or innovative products. This proposal supports the reality of innovation as the result of R&D activities in several technological and scientific applications.

Description of Index Components and Their Logical Bases

- Even though the R&D system is considered an innovation output, it has been chosen to represent, in and of itself, a main component of the Arab countries' entry to the era of knowledge. This methodological choice is based on several factors:

  - The absence of an R&D culture in service and industry institutions, which leads to difficulty in applying R&D results in these fields and, hence, to the lack of opportunities to produce knowledge and technological innovation at the Arab level;

  - Weak correlation and cooperation between scientific R&D institutions (that offer research services) on the one hand, and production companies and civil society institutions (that request research services) on the other;

  - Marked deficiency in the abilities of graduates from educational institutions in the area of R&D demanded by labour markets in the Knowledge Age of the third millennium;

  - Inadequate research infrastructure in the Arab World and its inability to keep pace with modern trends, especially in terms of infrastructure that aims to link scientific research with society (such as scientific retreats, research innovation centres and industrial nurseries).

- As scientific R&D and innovation each require a suitable economic, social and cultural environment and IT structure in order to keep pace with the Knowledge Age, it was agreed that several supporting infrastructural and environmental indicators should be composed that prompt the evolution of scientific research on the one hand, and the trend towards technological and non-technological innovation on the other. Therefore, the composite R&D and Innovation Index has been divided into three sub-indices peculiar to R&D, innovation and a more favourable environment for their production, wherein this structural design allows for the division of the sub-indices into pillars, sub-pillars, and indicators that contribute to the formation of the AKI.

- According to conventional economic reasoning, the composite index outputs include two basic types: the first pertains to elements of the formation of the value added (such as labour, capital and technological advancement), while the second contributes to the measurement of intermediate inputs (supporting elements of R&D or innovation processes, such as power required for the operation of equipment, research equipment and productive services required by the productive process).

- In so much that creativity and technological innovation processes are considered to have an effective impact on economic and social development rates, it is expected that a more extensive set of environmental variables will be allocated for these processes.

- In keeping with the current trend, the proposed structure for the scientific R&D and Innovation Index seeks to connect scientific research to commodity markets and societal demands and services through the full cycle of scientific research, development and innovation that starts with the exploration of research trends for basic and applied research, and arrives at societal influence through innovation.

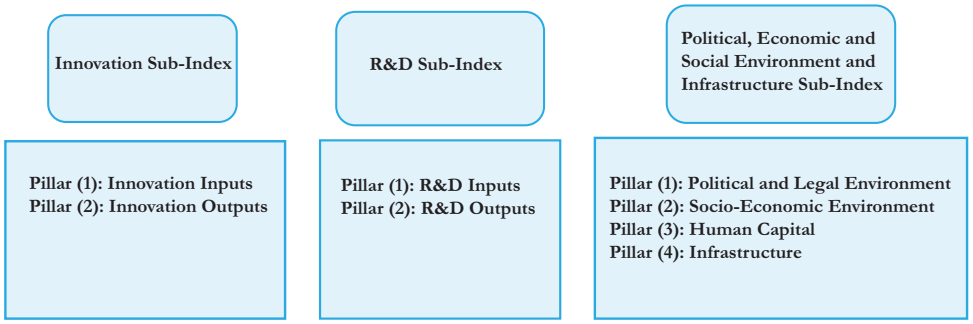
- Based on the international definitions of R&D and innovation discussed above (Frascati Manual and Oslo Manual), the R&D project is split into basic research, applied research and experimental development. Innovation is split into technological innovation (product innovation and the innovation of productivity processes) and non-technological innovation (innovation in marketing or in the organisational structure of service and productivity institutions).

Complete Structure of the Composite Index for R&D and Innovation

Overall, the design of the R&D and Innovation Index for the Arab countries has taken a common approach in expanding the scope of innovation assessment to include a comprehensive set of institutional, political, societal, economic and environmental variables, while at the same time maintaining the concise definition of the inputs and outputs of the innovation process (Figure 3-A). Owing to the socio-economic development and technological advancement of the Arab countries, research and development have been regarded as two important determining factors in the process of innovation in the region. This situation was reflected in the conceptual design by considering R&D inputs and outputs as one of the three sub-indices

Figure 3-A:

Overall Structure of the Composite R&D and Innovation Index



making up the structural index. It is also worth noting here that proper implementation of R&D activities is also influenced by a set of institutional, societal, political, economic and developmental factors that should also be taken into consideration.

The chosen structure of the R&D and Innovation Index includes a number of sub-indices, pillars and indicators as follows:

- The R&D sub-index is divided into two pillars for inputs and outputs according to the Frascati Manual developed by OECD in this field and adopted by UNESCO. Similarly, the innovation sub-index includes two input and output pillars corresponding to the Oslo Manual, which represents the prevailing reference in this field. Based on the methodological choice for the index, both R&D and innovation are each treated as a productive process that includes several inputs and outputs. As for the political, socio-economic, and institutional sub-index, this includes four pillars as illustrated in Figure 3-A.

- Figure 3-A divides the R&D inputs into three sub-pillars: R&D expenditures, human resources (researchers, technicians and supporting body), and sources of funding for R&D, according to the definition of UNESCO's Statistical Institute. In keeping with UNESCO and the OECD, R&D outputs are organised into three categories: scientific publication, patent statistics and the balance of payments for high-tech products.

- Innovation inputs are determined by a number of sub-pillars that are related to activities carried out within the innovation framework. Because innovation in general requires advanced knowledge sources and institutional cooperation with bodies concerned with R&D, with a view to

Figure 3-B:

R&D Sub-Index

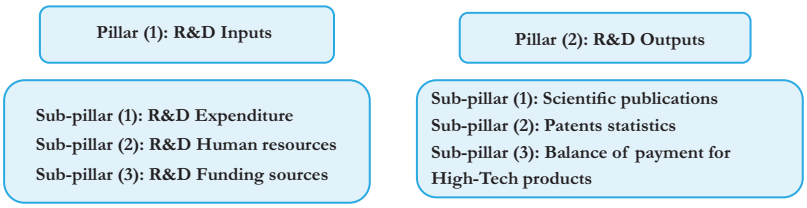
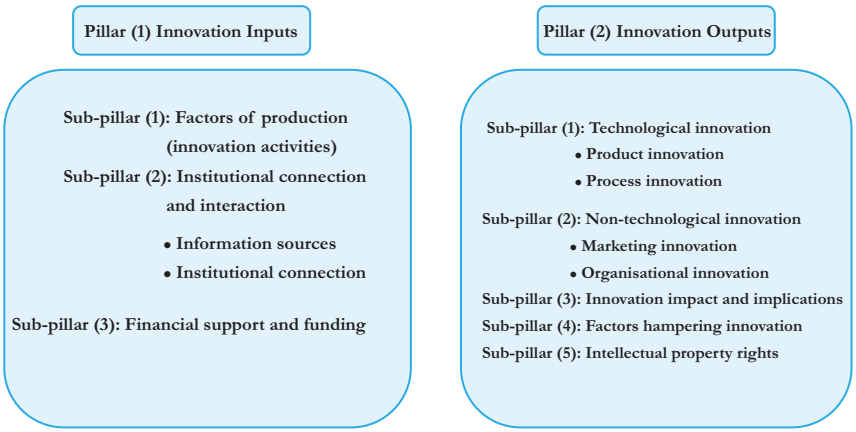


Figure 3-C:

Innovation Sub-Index



the creation of socio-economic and societal impacts, the second sub-pillar of innovative process inputs has been restricted to sources of information and institutional connection (Figure 3-C). Naturally, the financial support for innovation is the third sub-pillar of innovation inputs.

- According to OECD's Technology Innovation Index, and in keeping with the UNESCO approach, creative innovation outputs are defined as an important development for a product, productivity process, marketing method or organisational process in industrial and service units. However, these outcomes should also be measured by the societal impact on the economic and social system, in addition to a number of indicators of the disruption of innovation efforts. Measured outputs of innovation are represented in the statistics of intellectual property rights. According to the general, prevailing approach for measuring R&D and innovation indices, the environmental indicators and the infrastructure affecting innovation efforts are divided into four pillars: political and regulatory environment; social and economic climate; human capital; and infrastructure. Each pillar includes a complete set of sub-pillars that contribute to creating a climate and infrastructure which pave the way for creating an innovative society with an effective scientific base for scientific R&D (Figure 3-D).

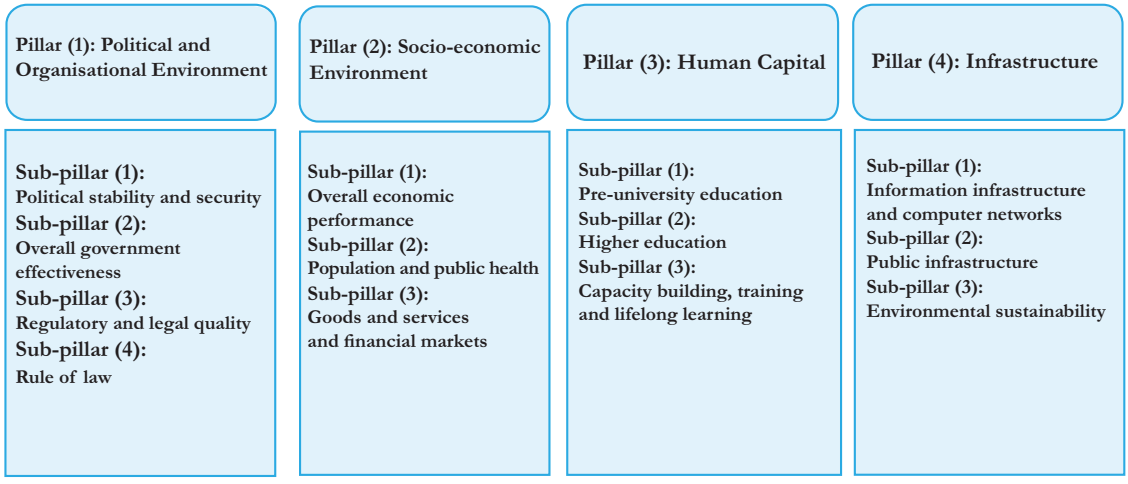
Data Sources for the Index Components

The international development reports of the World Bank,[15] the Economic Outlook issued by the International Monetary Fund (IMF),[16] as well as various international information technology reports have all been drawn upon to ensure that the R&D and Innovation Index includes a complete range of political, economic, social and cultural and environmental indicators. It also includes infrastructure variables, in particular to capture the structure of communications and information. Some of the indicators for scientific R&D and innovation relied on the Global Competitiveness Report issued by the World Economic Forum.[17] The project work team reviewed some of the national reports and publications of the Arab countries issued through scientific research and technology academies and ministries of scientific research, particularly from those countries with science and technology observatories.

Verification of the Proposed Index Through Individual and Group Consultations

For verification of the methodological construction of the composite index for R&D and innovation in the Arab countries, the AKI project has adopted the method of individual and group consultations. A workshop was held for this purpose in September 2015 that brought together twelve Arab experts and scholars in the field of R&D and innovation to discuss the conceptual framework and

Figure 3-D:
Political, Economic, Social Environment and Infrastructure Sub-Index



components of the R&D and Innovation Index. To obtain the most representative weights for the Index, part of the workshop was devoted to discussing the issue of weights and proposing weighted averages, in accordance with the budget allocation statistical approach.

The specialised workshop contributed to agreement on several points associated with the conceptual framework, the arrangement of the Index and the possible weights of the indicators:

- Participants agreed to include R&D and innovation in one structural framework that defines the inputs and outputs of each, the indicators representing the political, economic and social environment, infrastructure support for their activities and the infrastructure necessary for their function;

- In considering the current conditions of the Arab countries, and following extensive discussions, the participants approved the allocation of heavier weights for the R&D sub-index (to be evenly distributed between its inputs and outputs), while agreeing to increase the weight of the innovation outputs over its inputs;

- Experts participating in the workshop reviewed environmental indicators and infrastructure variables that supported both R&D and innovation. They proposed to divide a limited number of aggregated indicators and merge others, as set forth in the structural, conceptual framework and the Index's sub-indices.

Statistical Analyses of the Composition of the Composite Index for R&D and Innovation

To verify the methodological choices for the components of the R&D and Innovation Index, the data collected to fulfil its main and sub-pillars and their indicators were subjected to a number of statistical analyses, with the goal of ensuring their consistency and ability to represent the composite index variables. The Cronbach's Alpha coefficient measurements and the interpretation index rate showed acceptable and consistent performance overall. In some cases, lack of data contributed to the difficulty of assessing statistical indicators and allocating weights for sub-indices. It was also noted that the pillars specific to innovation inputs and outputs - based on a sample statistical survey method - have been observed at the level of only two Arab countries, which makes it impossible to compose the desired indicators in this field. This matter absolutely necessitates emphasis on the completion of statistical surveys for innovation in the other Arab countries. Although this methodology, adopted by both UNESCO and OECD, is the most comprehensive and consistent in measuring inputs and outputs of the innovation process, as an alternative trend in this context a comprehensive set of indices indicating innovation outputs have been chosen according to Global Innovation Index trends. In general, the results of statistical indicator analysis point to the consistency of the selected variables.

Assessing Weights of the R&D and Innovation Composite Index

The most important factors affecting the consistency of the Index and its analytical capacity are the weighted averages of the components of the R&D and Innovation Index, the weights of its main, sub-pillars and sub-indices that indicate scientific R&D and innovation system performance in the Arab countries, and the characteristics and rates of this performance. Generally, weights are chosen to reflect the relative importance of composing the aggregated index and assessing its numerical value. The various weights have been assessed based on three entries:

- The methodological outlook that directs the selection of analytical indicators and the results of previous studies in this field;
- The outputs of individual and group consultations through specialised workshops;
- The statistical assessment of the weights.

Accordingly, the project work team has arrived at a range of options described below, noting that this section only provides the weights of the main components of the overall composite index and their main and sub-pillars. The reader is referred to Table A6 in the appendices for the details of the remaining sub-divisional weights.

In light of a critical analytical reading of international approaches adopted in the field of R&D and innovation indices (the second part of the report), and the vision of constructing the composite index discussed in the third part of the report, and taking into consideration the outcomes of individual and group consultations, it was agreed to allocate a high weighted average (equal to 40 per cent) to the composite sub-index for R&D, evenly distributed between the inputs and outputs of R&D. Due to the prevailing global trend in also considering political, economic, societal and institutional factors and their importance in creating an "innovative society" capable of using R&D to create a modern knowledge climate, 35 per cent of the composite index was allocated for the environment of innovation, compared to 25 per cent for the sub-index of innovation

R&D Sub-Index: Equal, proportional weights were allocated to inputs and outputs (50 percent), distributed as follows: 45 per cent for research human resources, 35 per cent for R&D expenditures, and 20 per cent for sources of funding. Although statistical tests led to equal weights for R&D expenditures and the preparation of researchers, analytical reasoning was considered preferable in light of the clear lack of availability of data. As for the outputs, there was agreement to allocate for the first sub-pillar (scientific publications) and the second sub-pillar (patent statistics) equal weights of 40 per cent each; with a weighted average of 20 per cent allocated for the rate of imported high-tech products to total commodity imports.

Innovation Sub-Index: Due to the lack of availability of sufficient data to conduct a statistical analysis of the indicators of innovation inputs and outputs, the assessment of the weighted averages relied both on the methodology and the analytical goal of the project, as well as on the results of individual and group consultations. The convergence of the weights of both the sub-pillars of the innovation activities and the institutional and information connection was agreed upon, giving proportional distinction to the activities of innovation production and its elements. These activities were allocated a weighted average of 40 percent, with an allocation of only 36 per cent for the institutional and information connection, while the proportional weight of diversity in innovation funding did not exceed 24 per cent of the total assessment of innovative inputs. With regard to outputs of innovation that may occur in products, productive processes, marketing or administrative organisation as a direct result of R&D and activities geared towards innovation within a productive or service company or organisation, or through the influence of the economic, political, and cultural climate variables of the country and its suitable infrastructure for innovative activity, all the individual and group consultations unanimously agreed to allocate a larger weight, assessed at 60 per cent of the pillar indicating innovative process outputs. These were distributed as follows: 20 per cent for technological innovation, 20 per cent for non-technological innovation and 30 per cent for intellectual property rights. 30 per cent of the total weighted average was allocated to and divided evenly between the societal impacts and the factors that impede innovation.

The lack of availability of indicators for innovation inputs and outputs for the Arab countries - in accordance with the methodology adopted by the Oslo Manual and UNESCO – has proven to be an obstacle to the possibility of assessing an appropriate composite index for R&D and innovation (data available for only two Arab countries). To resolve this inadequacy, several indices indicating innovation or reflecting its major outputs have been measured in accordance with the approach used for developing the GII.[18] As the sub-index derived from the GII includes the indicators for the impact of innovation and the spread of knowledge and indicators of creative outputs, it was agreed to distribute the weights in equal proportion

between these two pillars. The weights for the impact of innovation and the spread of knowledge have also been distributed evenly over its seven specific indicators.

The sub-index for the political, economic, social environment and infrastructure includes a broad list of indicators arranged into four pillars and granted the following weights: 32 per cent for human capital, 32 per cent for infrastructure, 14 per cent for the political and legal environment and 22 per cent for the socio-economic environment. This is due to the impact of the human element - which is capable of interacting with the data and characteristics of the Knowledge Age – on the performance of the R&D and innovation system on the one hand, and the need to rely on an informatics structure and an environment suitable for accomplishing research and innovative activities on the other.

- Political and legal environment: The results of the statistical analysis of the indices gave equal weights to the four sub-pillars, but the participants of the specialised workshop chose to put the effectiveness of the public sector at the top of the list; hence, the sub-pillar for public sector effectiveness obtained 40 per cent of the total weight. The participants also agreed to allocate 25 per cent for political and security stability.

- Economic and social environment: 50 per cent was allocated to commodity and service markets and to spot/cash markets, compared to 30 per cent for overall economic performance and 20 per cent for population and public health. This choice - affirmed through individual and group consultations – is due to the growing importance of and requirements for the existence of specific mechanisms for market functioning, and the level of desired complexity to serve the purposes of R&D and innovation, as well as the impact of macro-economic performance on the general climate and the innovation-fostering environment.

- Human capital: A medium weighted average assessed at 45 per cent was allocated for higher education and its various institutions for being the most capable of providing the required human resources in the Knowledge Age on both the education level and research capacity. Due to the growing interest in trends in lifelong learning and continuing education, as well as in present strategies, 20 per cent has been allocated for these trends. The role of pre-university education in the formation of students' personalities and preparing them for higher education and graduate studies obtained a weight worth 35 percent.

- Appropriate infrastructure: The workshop participants agreed to allocate a weight of 45 per cent for IT structure, 35 per cent for the public infrastructure, and 20 per cent for the environmental sustainability indicator.

It is noted here that the statistically estimated weights for the sub-index on the political, economic, social climate and infrastructure have only dealt with sub- or individual indicators, possibly due to inadequate data and indicators available in this field. Because the overall trend for the statistical analysis of this sub-index (especially the infrastructure pillar) stressed the convergence or evenness of the weights for the indicators, and in the absence of other distributional standards in this area, the project adopted the principle of equal weighted averages for the infrastructure sub-indices.

Conclusion

The Arab Knowledge Index is a composite index linking the variables of R&D to the efforts of technological and non-technological innovation by virtue of their active role in the production, localisation and use of knowledge - all considered important factors contributing to accelerating economic growth rates and supporting sustainable development. The Index as a whole, and its incorporation of these factors, is premised upon the acknowledged need for an Arab research base that can support innovation that contributes to the desired paradigm shift in economic and social development. In order

to achieve this development objective by offering a tool for monitoring, the composite index includes three sub-indices specific to R&D, innovation and environmental variables in the fields of economics, sociology, politics, institutional and legal framework, and business climate, in addition to the indices indicative of the availability of an appropriate IT structure.

The methodology for constructing a composite index for R&D and innovation relied on three main steps. The first step was carrying out a desk review of relevant international and regional studies and reports and their resulting composite indices, aggregated indicators and repositories of data and analytical indicators specific to scientific R&D and innovation. The second step entailed individual and group consultations with experts and stakeholders. The third step involved applying statistical analysis methods to test indicators and assess their weighted averages. The statistical results verified the consistency of the selected variables. Unequal weighted averages for individual variables were used in order to construct sub-indices specific to the R&D and Innovation Index.

The preparation of the composite index for Arab countries was negatively affected by a clear insufficiency of data based on statistical surveys and analytical indices in the field of R&D and innovation, despite the outstanding efforts of OECD to compose definition manuals for them. UNESCO also provides a coherent and integrated framework for regulating analytical indicators. Moreover, UIS, World Bank, and UNDP have their own databases in this field. Excluded from this are indicators that monitor the change in the economic, social, political and institutional climate, as well as the variables in IT infrastructure that support scientific R&D and innovation. The available data reveal that all the analytical indices of the Arab countries are incomplete, while the innovation indicators – that rely on conducting a statistical survey – are only available for two Arab countries. Thus, the indicators in the field of scientific R&D for the Arab countries should be completed in order to ensure the consistency and quality of the composite index proposed for the current project.

Endnotes

1. Ministry of Scientific Research – Egypt 2008; Bassanini et al. 2000; OECD 2008a; Paunov 2013.
2. Motaz Khorshid 2006 (reference in Arabic); Khorshid 2015b; OECD 2002, 2004 & 2013; Saleh 2011; UNDP & Mohammed bin Rashid Al Maktoum Foundation 2014 (reference in Arabic).
3. OECD 2002.
4. OECD 2013; Cornell University et al. 2015.
5. OECD 2004; Hollanders et al. 2015.
6. Khorshid 2015b.
7. Khorshid 2015b; Ministry of Scientific Research- Egypt 2008 (reference in Arabic).
8. Hollanders et al. 2015.
9. Cornell University et al. 2015.
10. The Economist Intelligence Unit 2014.
11. OECD 2002 & 2005.
12. OECD 2004, 2008 & 2013; Paunov 2013.
13. UNESCO 2010 a&b; World Bank 2007 & 2008a.
14. Cornell University et al. 2015; Hollanders et al. 2015; Khorshid 2015b; OECD 2008.
15. World Bank 2015b.
16. International Monetary Fund 2015.
17. World Economic Forum 2015a.
18. Cornell University et al. 2015.