A NOVEL COMPOSITE INDEX FOR REGIONAL INNOVATION ASSESSMENT WITH AN APPLICATION TO EGYPTIAN GOVERNORATES[*]

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Abstract. Innovation can be classified based on the type of its outcome which includes knowledge and technology, creative and cultural outcomes in addition to intangible assets. Innovation composite index is generally designed with the purpose of estimating the innovation capabilities and competencies of different governorates or regions. In this work, a governorate innovation composite index (GICI) is constructed and applied to the Egyptian governorates to evaluate the efficiency and effectiveness of adopted innovation measures and policies in these regions along with the assessment of the societal impact. Considering standard type of innovation composite indicators, the Egyptian index proposed in this work is conceptually broken down into a set of innovation inputs and outputs composing its production function. Inputs are divided into factors which are used to produce innovation output while considering specific enabling factors. The application of the innovation governorate index to the Egyptian context has delineated general as well as specific results. First, Innovation performance of governorates measured by the value of the composite index, shows a moderate attitude, whereas input sub-pillars for governorates are however on the low side. In light of this finding, Egypt's government needs to consolidate efforts towards enhancing the

capacity of innovation inputs. Second, the mean value of the governorates output pillar ranged from 53 to 99 percent. Based on this finding, the Egyptian government needs to adopt an integrated policy package to achieve the balance between input and output parameters of innovation. Finally, this paper suggests that the difference in innovation performance between regions should be considered as an important part in developing national innovation strategies.

Keywords: Innovation production function, composite index, regional innovation; benchmarking; innovation metrics.

JEL Classifications: O31, O32, O38

1. Introduction

The recent *Oslo Manual* (OECD and Eurostat, 2018), defined innovation as "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)". This definition also includes the generation of new ideas, as well as the recombination of existing ideas. Given this rationale, the minimum requirements for an innovation must be new (or significantly improved) product, process to the firm (OECD,2018). Other international organisations such as the United Nations Educational, Science and Culture Organization (UNESCO) and the World Intellectual Property Organization (WIPO) have favoured also this definition (UNESCO, 2013).

Innovation drives economic growth, improves welfare of citizens, supports the transformation of countries to the knowledge era and helps to address social challenges (OECD, 2010a, Bassinini et al 2000, Pessoa 2010, OECD 2004 and 2010, EBRD 2019, Khorshid 2018, Khorshid and Ismail 2019). Innovation is considered a key driver to economic growth and competitiveness. Many traditional industrial economies are now in the process of transformation to a knowledge Economy, where innovation is considered one of the mains drivers for the transformation process, as well as a major factor for sustained economic development (Grupp and Mogee, 2004). Furthermore, many countries today are developing national plans in order to enhance their innovative capacity, with an aim to improve the growth prospects of their economies (Porter, 1999). The outcomes of innovation are often measured in terms of creative outputs such as , significant increase in sales from new products, significant reduction of a manufacturing processing time or the frequency of new product launches (Sofka, 2010, Laursen, 2006).

Innovation activities does not occur only in business sector or industrial companies but can also happen in any non-profit organization, cities, governorates, regions and countries at large. International studies show different levels of composite innovation indicators, such as product or process innovation, creative services, marketing and organisational innovation (Radwan and Sakr, 2018). Moreover, innovation generally requires collaboration with different stakeholders for knowledge, technology and risk sharing. An important type of innovation refers to the ability to make major improvements and modifications to existing technologies, or create new technologies (Furman, 2002). Many studies have been trying to measure innovation through creating an innovation complex index. An innovation index is a concise quantitative measure of the innovative capability of institutions, businesses or countries (Aspen Institute Italia 2007).

Moreover, composite innovation index represents a tool to measure, monitor and promote progress of the innovation performance in a company, region or country. The index could also serve as a quantitative benchmark highlighting the interaction between inputs and outputs of innovation and could help to assess policy means needed to boost innovation, to achieve economic growth and create new jobs. Furthermore, composite innovation index highlights policy challenges, and support the development of policies to draft new national innovation strategies (Jarunee, 2010).

On other front, innovation statistics can be used to evaluate the effectiveness of government public science and technology policies, and to compare the position of countries regarding innovation performance. Recently, several studies have developed composite innovation indices over the years to assess countries' positions and to evaluate the effectiveness of governments' interventions regarding innovation policies and strategies (Mahroum & Al-Saleh, 2013). Thus, several international institutions developed a range of innovation indices, (the European Innovation Scoreboard, the National Innovative Capacity Index from the World Economic Forum, the UNCTAD's indices, the Innovation Index of the World Bank, the Nordic Innovation Monitor, the OECD Science, Technology and Industry scoreboard, the Bloomberg Innovation Index, and the global innovation index or GII (Mahroum & Al-Saleh, 2013).

The analysis of composite indices helps policymakers and governments throughout the world to identify paths for future design and development of innovation policies. Based on recent literature, innovation is measured at different levels, starting from the level of a world geographic region, a country, a locality, a city or a company. In the recent years, we can find many studies aimed at measuring innovation at the city level, (Ergasakis et al., 2004), and others have developed specific metrics and indicators to provide a comparative assessment of the innovation performance of nations and regions (Dvir and Pasher, 2004; Metaxiotis et al., 2006; Scheel, 2011).

The purposes of this paper are; (i) to identify and articulate the linkages between innovation, research and development (R&D), science and technology strategies and economic development, (ii) to develop the multidimensional conceptual model of innovation, (iii) to assess alternative approaches to construct a composite innovation index, (iv) to develop a conceptual model for estimating a governorate innovation composite index (GICI) and (v) to use this model to estimate a composite index along with its inputs and outputs for the Egyptian governorates, and finally, (vi) to assess the innovation efficiency, effectiveness and impact of Egypt's governorates based on the developed composite index and its pillar, sub-pillars, sub-indicators and variables. Given these analytical objectives, the paper is organized around four sections. The first section summarizes the role of innovation in socioeconomic development, identifies the multi- dimensional structural model of the innovation process, and explains alternative approaches for its estimation and assessment of its impact. Section two develops the conceptual structure of the governorate innovation composite index (GICI), particularly constructed to evaluate innovation inputs and outputs of the Egyptian governorates, and describes as well the methodology used to estimate its pillars, sub-pillars, sub-indicators and Variables. Section three is devoted to the analysis and discussion of the obtained results. Finally, section four includes the concluding remarks and policy recommendation, followed by the list of references.

1.1. Innovation for development

In the Oslo Manual developed by OECD in 2005 and adopted by the UNESCO, innovation is defined as "creative activity leading to the development of new (or significantly improved) products (goods and services), processes, marketing methods and organizational models" (OECD 2005, UNESCO 2017). In the recently developed OSLO manual of 2018, the revised definition states that " innovation is a new product or process which differs significantly from the product previously delivered to consumers or the process previously used by the company
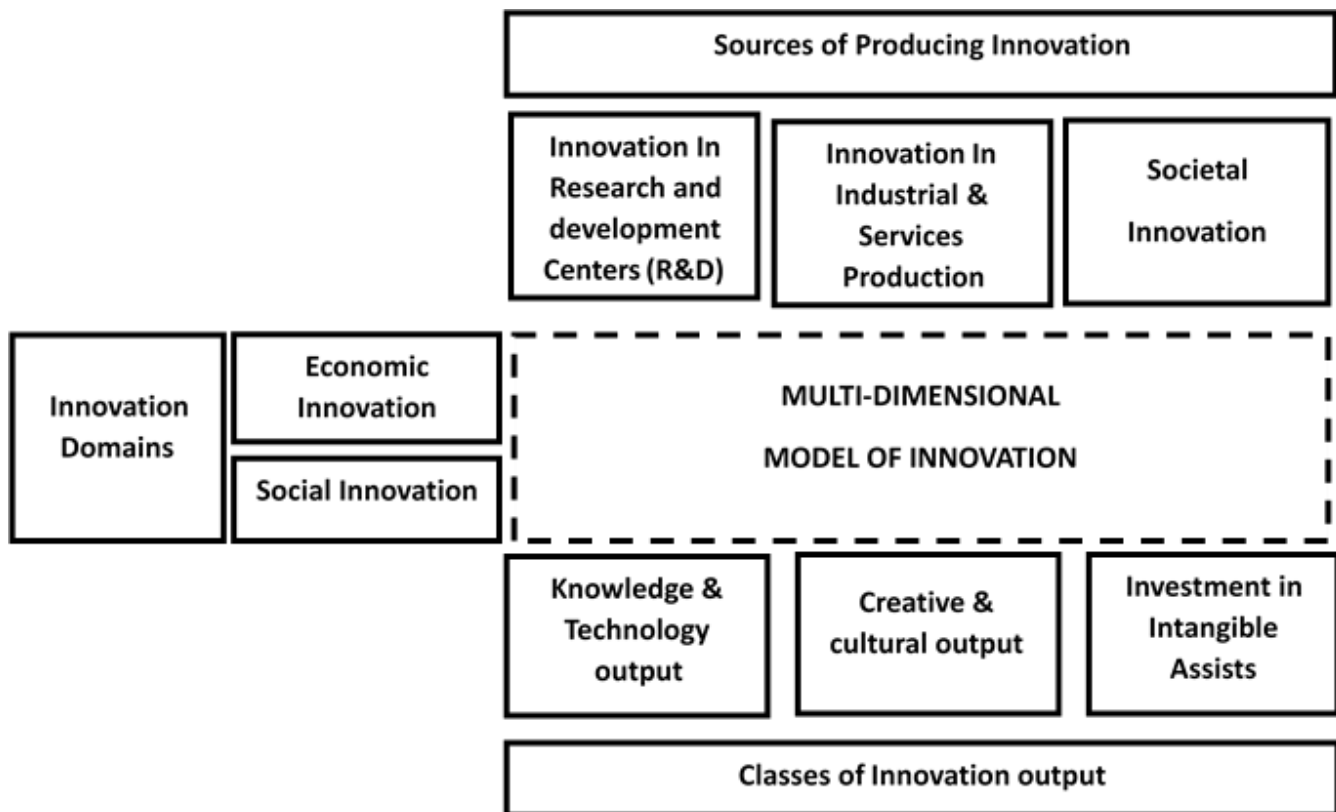
or the industry (OECD and Eurostat 2018). Based on this recent definition, OSLO Manual makes the difference between "Product Innovation" and "Business Process Innovation". Furthermore, based on OSLO Manual, "Innovative Activities" include all Development, organizational, financing and commercialization operations leading to the implementation of product or process innovation. Based on the above rationale, "an innovative company or institution "is a company that produced (or capable of producing) product or process innovation during the last two to three years. It is worth noting that innovation product or process should be implemented and generates societal impact. Product innovation should be used by consumers, and process innovation should be applied by a company or institution. Because innovation generally produces new (or significantly improved) products or processes, with different characteristics and better technical or behavioral features, one would expect that innovation will have an accelerating impact on growth and welfare prospects of the society in general, and the economic system in particular. On the other hand, innovation differs from research and development activities in several ways. First, innovation represents a more advanced level of development compared to research activities. It corresponds to the complete cycle of research that begins with basic and applied research, experimental development, prototyping and modeling, and finally with commercialization and marketing. Innovation can be produced however outside the research institutions based on knowledge worker's advanced skills and competences. As such, innovation generates considerable impact on markets of goods and services, and the value added generated within the production activities. It should be noted finally that innovation represents generally a basic feature of the knowledge Economy and society. Based on the above definitions and rationale, innovation is considered an important factor for transforming countries to a knowledge-based economy and achieving socioeconomic sustainable development. (Radwan 2018; Khorshid 2018; EBRD 2019).

1.2. Multi-dimensional Innovation Model

Given its sizable impact on markets of goods and services, the performance of production activities, and the society at large, innovation can be conceptually represented by a multidimensional model. As shown in figure (1), the studies on innovation as well as approaches for estimating its impact are grouped into three categories or dimensions including; i) sources of producing innovation, ii) innovation domains and iii) classes of innovation Outputs (Khorshid 2019). With respect to the "first category", innovation can be generated (or produced) as part of the research and development activities. In principle, the complete research cycle that begins with examination of natural phenomena, carrying out basic and applied research, undertaking experimental development and designing prototype models, ends generally with new commercialized products or new production processes (as an innovation output). This "first innovation producing model" is generally associated with the construction of advanced or modern R&D Infrastructure such as "science and research parks" and "advanced technology valleys", in order to establish the linkages between university research centers and other knowledge producing unites on one hand, and the demand of industries, services and society at large, on the other hand . This first model satisfies also the 4 P's approach of research and development Outputs (namely, Published Papers, Patents, Prototypes and Products), (Khorshid 2015 a). Another source of producing innovation, is the business sector (or commodity producing companies). The outcome of this production category is generally represented by new or significantly improved goods, services, managerial models or marketing methods. The innovation in production activities is analyzed in detail in OSLO manuals. The estimation of innovation inputs, outputs, and efficiency according to this model, is carried out using community statistical surveys. These surveys are broken down into innovative activities, creative linkages (such as sources of information and institutional cooperation), and financial support, as innovation inputs. Innovation outputs are classified as technological and non-technological innovation products, innovation impact, innovation barriers and intellectual property income, (Hollanders et al 2014, European Commission 2017 and ESTIO 2015).

Finally, innovation can be produced, outside the research centers and the production sphere of the economy. This happens generally with societies characterized by creative, highly skilled and educated labor. This innovation model is named as "societal innovation". As a source of producing innovation, this model demands modern and technology advanced environment which coop with the knowledge era and the fourth industrial revolution of the twenty-one century, highly skilled population, and favorable enabling economic and social environment. (UNDP 2016 2017 and Dutta et al 2014). The societal innovation emerged for the first time, as a source of creative products in developing the global innovation index (produced by the world intellectual property income (WIPO), Cornel University, and INSEAD).

Figure (1). Multi-dimensional Innovation Model

Based on this new concept, Innovation Index should reflect a socioeconomic phenomenon explaining scientific, cultural and education levels of the society at large, including skilled and competent knowledge worker, advanced manufacturing technology, and socioeconomic and institutional infrastructural supporting innovation activities. Based on this specific rationale, R&D indicators represent only one input to innovation that should be complemented by education and human capital, physical and computing infrastructures, efficiency of economic markets, effectiveness of business sector and appropriate institutional system to close the circle of innovation inputs. Based on This new vision, innovation outcomes are generally broken down into knowledge and technology outcomes, creative and cultural outputs and intangible assets (Dutta et al 2014).

As shown in figure (1), innovation can be also classified according to its domain of application. In this respect, innovation in economic or social domain is identified. Social innovation is defined by the World Bank as a creative activity directed to address social challenges that cannot be handled by market economies. Given this rationale, social innovation produces new services with the purpose of significantly improving living standards of citizens, as well as their welfare measures. This type of innovation seeks to adopt appropriate policies leading to the integration of labor markets, the creation of new cognitive skills, and the development of new job opportunities. As such, social innovation addresses mainly the social dimension of innovation. On the other hand, innovation in economic domain aims at creating new or significantly improved marketed goods and services in order to enhance productivity and economic growth prospects. Meanwhile, Economic innovation addresses the creativity of production processes and marketing policies. As such, it is considered the corner stone for accelerating the economic development process of a country (World Bank 2007 a,b).

The third "dimension of innovation" is the nature and character of its outcome and impact. Here, we can identify three categories of outputs, knowledge and technology output, creative and cultural output and investment in intangible assets (Cornell University, INSEAD and WIPO 2018). Knowledge and technology outputs are generally classified into knowledge production, impact of knowledge and knowledge dissemination. Knowledge dissemination is represented in the world wide innovation composite indices by a number of variables such as income from property income, high technology exports, ICT exports and foreign direct investments (FDI), especially those directed to knowledge creation and increasing its stock. On the other hand, knowledge impact is assessed by a set of variables such as labor force productivity, intensity of establishing new business enterprises, spending on computer programming, and high technology industrial production. Finally, knowledge creation is generally estimated using number of patents, number of published papers, and number of scientific citations in international journals (Cornell University, INSEAD and WIPO 2018,,Dutta et al 2014, Khorshid 2018). The final innovation output is concerned with "creative and cultural" products. These products relies primarily on creative and knowledgeable human capital that produces new (or significantly improved) ideas, visions, artistic and culture products that can be measured for example by the percent of creative and culture exports to total size of foreign trade, number of artistic films to population size in millions, size of entertainment and advertising markets per thousands of population, and output of printing and publishing industries as a percent of transformation industries (UNDP 2016, 2017 and Khorshid et al 2018).

1.3. Approaches for Estimating Innovation

Despite the important role of research and development (R&D) statistics in drafting national science and technology policies and strategies, they do not represent sufficient conditions for assessing the transformation process of societies to a knowledge Economy. It becomes necessary in the knowledge era, to investigate these statistics in light of their contribution to social and economic development. This process can be ensured by measures related to innovation (figure (2)). Given the multi-dimensional and diversifying nature of innovation activities, the innovation indicators should reflect the modernization of society and its knowledge creation capacity via an integrated research and development system, knowledge intensive high value added industries, creative and cultural products, skilled human capital, enabling socioeconomic and institutional environment, and finally an appropriate physical and computational infrastructure. In figure (2), innovation is globally estimated using two alternative approaches or models. The first approach adopted by UNESCO and OECD organizations, treats innovation process as a production function with input and output indicators. Output indicators of the innovation process is divided into product, process, organizational and marketing innovation. Output statistics include also measures of the resulting impact and different barriers of innovation. Inputs include factors used in the production of innovation output, information in support of innovation as well as institutional cooperation and

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financing means. The second approach assumes that innovation is in principle created by educated, skilled, competent and knowledgeable societies. Innovation statistics should coop with this hypothesis by enlarging the scope of their inputs and outputs. On the input front, indicators are grouped under socioeconomic, institutional, physical and information infrastructure (commonly known as enabling environment), in addition to other physical inputs such as research and development, education and training, patent statistics and finance. Outputs include in principle knowledge and technology innovation as well as creative and cultural outcomes. Based on this second approach, a number of worldwide indices are currently developed to estimate innovation inputs, outputs, efficiency and impact. These are the global innovation index (GII) (Cornel University, INSEAD and WIPO 2018), OECD innovation output index (Vertesy and Derss 2016), Innovation union score board (IUS) (Hollanders 2014), and the Asian creativity and productivity index (CPI), (Khorshid 2018).

Figure (2). Approaches for Estimating Innovation

2. Methodology for Estimating the Egyptian Governorate Innovation Index

The Egyptian governorate Innovation composite Index (GICI) hierarchical structure includes 4 levels which are pillars, sub- pillars, sub-indicators and variables. To represent the production sphere of innovation, the composite index is primarily divided into innovation inputs and outputs. The sub-pillar level includes enabling environment

and the factors of production with respect to the input side while the other three sub-pillars represent the output side which are private-sector innovation support, marketing and organisational innovation as well as the societal innovation. Private innovation is directed mainly to citizens (or households) and investors and hence considered as sub-indicators. The remaining level of the composite index is composed of variables to be estimated using surveys and computed data. Each of these pillars, sub-pillars and sub-indicators is constructed in accordance with the standard international methodologies for the developing composite indicators (OECD 2008). In what follows we will explain in some detail the steps used in constructing each of these indicators.

2.1. Conceptual Structure of the Egyptian Governorate Innovation Index

The Egyptian governorate innovation composite index (GICI) is designed to reflect on one hand, multiplicity of purposes, sources of production, alternative domains and extending impact characterizing the innovation process, and to provide on the other hand, appropriate estimates to the components of its production function. The structure of the Egyptian governorate innovation composite index is illustrated in figure (3). As a production process, the composite index is primarily broken down into input and output pillars. The Input pillar is further divided into factors used to produce innovation Outputs, and their enabling environment (sub-pillars). The factors of production sub-pillar include human capital (composed of labor, education level, skills and competences) needed to generate creative processes, goods or services. The estimation of this sub-pillar depends on three sub-indicators related to the number of registered students in Ph.D. and MSc degrees, as well as the graduates of general secondary and vocational schools having advanced grades. These indicators reflect in a way the characteristics of the "knowledge workers" to be involved in the production of innovation products or processes. Another sub-pillar of factors of production is patent statistics. Patent statistics is considered an important innovation input that can be commercialized or marketed in the goods and services markets, if appropriate financing is afforded. According to the structure of innovation inputs, both new established small and medium industries, and advanced technology enterprises are considered also as a support to the creation of the innovation generated within the production activities producing goods and services.

Figure (3) illustrates also the enabling environment as part of the input pillar contributing to the Estimation of the Egyptian governorate innovation composite index (GICI). This sub-pillar is further disaggregated into the cooperation with research centers and universities in order to incubate creative ideas and generate innovation products or processes. Cooperation of research and innovation projects with the outside world, forms also another type of enabling environment. On the output front, the index estimates private innovation output directed to citizens and investors. This innovation support from governorates is done on a personal basis including services to households or private entrepreneurs. The second type of innovation is related to the significant improvements in the organizational structure of companies and their marketing policies. The last type of innovation output is concerned with innovative societies, characterized by creative human capital and advanced technologies, capable of coping with the knowledge era of the twenty-one century. This "societal innovation" is broken down into measures related to significantly improving the green economy and sustainable development, and other efforts directed to significantly modernizing and enhancing governorate's infrastructure.

Figure (3). Conceptual Structure of Egyptian Governorate Innovation Index

2.2 Variables Selection

The selection of the individual variables, included in the construction of each indicator (or sub-indicator), relied on a well-defined clear scientific methodology based on international and local literature. In addition, the concepts and experience from international organisations and agencies in estimating R&D and Innovation activities are employed.

Principal Components Analysis was used to confirm the consistency of the selected variables and their classification into various sub-indicators. These results supported the consistency of the conceptual design in selecting the variables and their classification into various subgroups, in which the explained variance ratio in most cases exceeded 50 per cent (Hair et al 2015). The results of the in-depth correlation analysis and alpha Cronbach coefficient confirmed the validity of the selection and classification of the variables, in which the alpha Cronbach coefficient exceeded 0.70 in most of the cases.

2.3. Data Collection and Organisation

The values of the 17 variables incorporated into the construction of the Egyptian GICI are collected using survey methodology. The survey questionnaire was designed by the Egyptian Science, Technology and Innovation Observatory (ESTIO) of the Egyptian Academy for Scientific Research and Technology (ASRT). The survey was designed and submitted to all governorates based on support from the Ministry of Higher Education and Scientific Research, and the Ministry of Local Development. The number of governorates participated in filing the questionnaire reached 22 governorates (which are Aswan - Port Said - Beheira - Beni Suef - South Sinai - Giza - Dakahlia - Damietta - Sohag - Suez - New Valley - Eastern - North Sinai - Western - Fayoum - Qalyubia - Qena - Kafr El Sheikh - Matrouh - Menoufia - Minya - Red Sea).

For the sake of transparency, simplicity and the possibility of repeating the results, no attempts were made to impute missing values to various variables. The use of the arithmetical mean formula in computing an indicator is equivalent of imputing each of the missing values of the indicator to the mean value of the variable. Data-processing was performed on the assumption that the data were error-free, the team having reviewed it more than once to ensure there were no errors in the data entry. The variables that might lead to a biased indicator value were treated using suitable statistical methods (Groeneveld and Medien 1984). It had been observed that some indicators were linked to other, Size-dependent indicators, such as population. These indicators were therefore rescaled using the size.

2.4. Normalisation and Weighting

The values of variables were normalised in the range [0,100] in which the higher values indicated better results. The rescaling or (maximum – minimum) method was used, in which the maximum and minimum indicate the largest and smallest value of the available indicator values respectively. The normalisation criterion depends on whether the variable is good i.e. has a positive relation with the overall index, or bad i.e. has a negative relation with the overall index. The good indicators are normalised using the following formula:

$$\text{Normalised indicator value of the governorate} = 100 \times \left(\frac{\text{raw indicator value of the governorate} - \text{raw minimum value of the indicator across governorates}}{\text{raw maximum value of the indicator across governorates} - \text{raw minimum value of the indicator across governorates}} \right)$$

In the case of the bad indicators i.e. indicators with an inversely correlated relation, the formula is adjusted as follows:-

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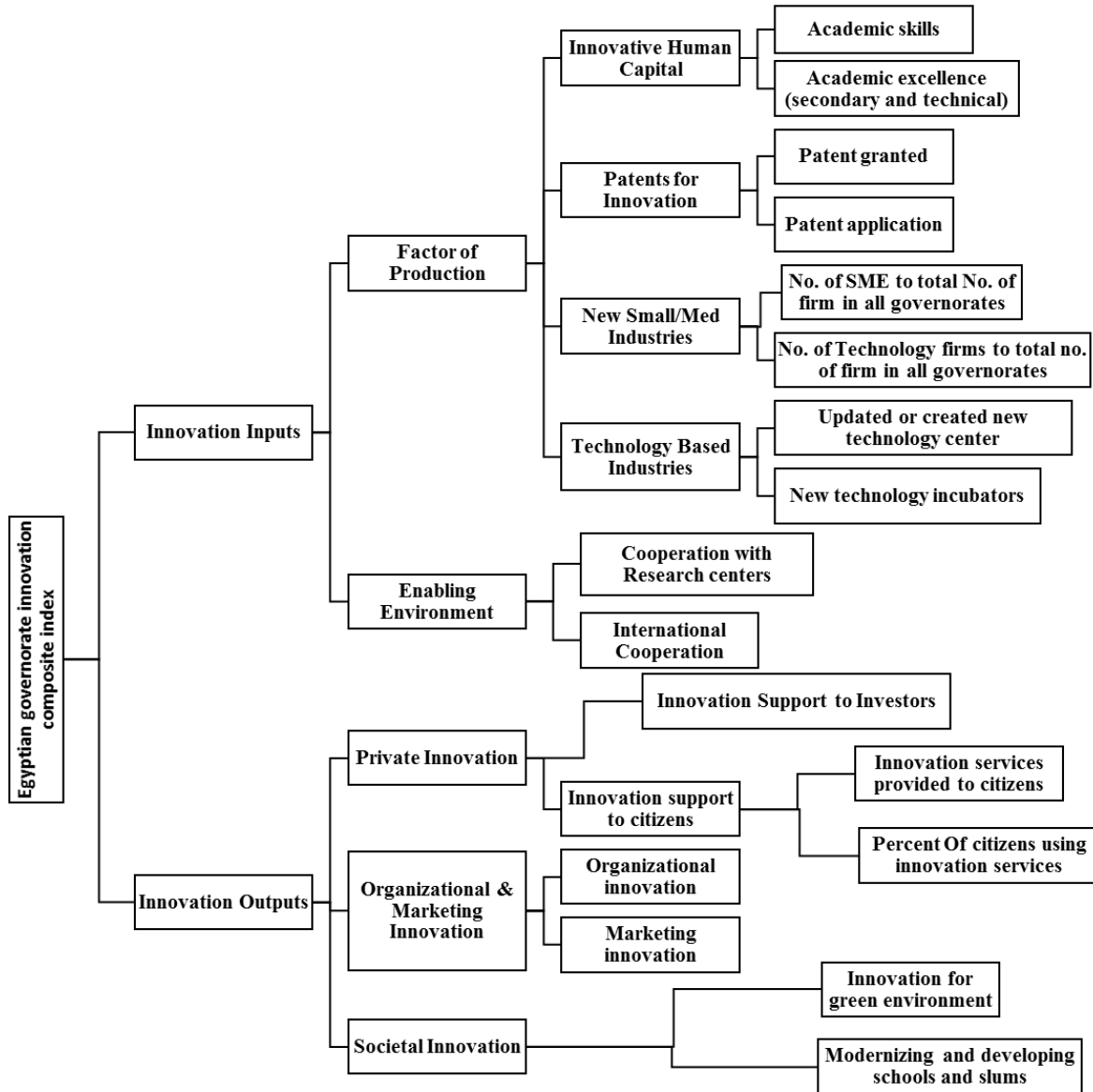Normalised indicator value of the governorate = 100 X

$$\left(\frac{\text{raw maximum value of the indicator across governorates - Raw indicator value of the governorate}}{\text{raw maximum value of the indicator across governorates - raw minimum value of the indicator across governorates}} \right)$$

Different weights are used in the construction of pillars, sub-pillars, sub-indicators and variables of The Egyptian Innovation Index. Equal weights are used in the absence of clear evidence of the diversity of significance of each indicator, as well as in the absence of sound and complete information concerning the existence of causal relationships or a lack of consensus on a classical method for estimating weights. In our case, the design and the disaggregation levels of the innovation index suggest the existence of logical differences , confirmed to some extend by statistical tests and scientific understanding, between the relative importance of sub-pillars, sub-indicators and variable with respect to their impact on the aggregate composite index. Although the pillar level suggests that aggregate inputs and outputs might have equal weights, the breakdown of the sub-pillar level assumes the existence of different weights. For example, we assumed that factors contributing to the production of innovative services of governorate are more important than their enabling environment. Furthermore, factors of production sub-pillar is composed of the two leading inputs to innovation which are the human capital for innovation and patent statistics, whereas the enabling environment in the index is limited to cooperation with research centres and universities and international linkages. Based on this rationale, factors of production sub-pillar is allocated 70 percent weight whereas the enabling environment is assigned 30 percent weight. Within the factors of production human capital for innovation, patent statistics, new established SME industries and technology based projects are assigned the following weights (40,30, 15,15) respectively. Based on the same logic and scientific understanding, the output pillar is decomposed into support to household service and private investors (with 40 percent weight), societal innovative services (composed of the green economy innovation and modernising infrastructure) with 40 percent weight. The remaining weight (20 percent) is allocated to innovation directed to improving marketing methods and enhancing organisational behaviour.

2.5.Index computation

The Egyptian Innovation Capital Index was calculated for 22 Egyptian governorates using the most recent and best available data for the various variables of each governorate. The values of the composite index for the Egyptian Innovation Index were calculated by applying a series of successive aggregations starting with the (more detailed level of) variables and ending by attaining the overall index.

The most well-known aggregations method is the arithmetic (or linear) method. The linear aggregation formula of the sub-indicators (SI_j) to compute the composite index *(CI)* takes the following form:-

$$CI = \sum_{j=1}^{n} w_j \times SI_j$$

Where CI is the proposed composite index to be computed, W_j is the relative weight of the sub-indicator SI_j, n the number of sub-indicators aggregated to form the composite indicator. The arithmetical (or linear) aggregation method is employed to compute all the Egyptian governorate Innovation Composite Index (GICI) pillars, sub-pillars, sup-indicators and Variables in this paper.

3. Analysis and discussion of the Results

The questionnaire was designed and implemented within The auspices of the Egyptian Science, Technology and Innovation Observatory (ESTIO) at the Academy of Scientific Research and Technology (ASRT), and it was submitted to all governorates with support from the Ministry of Higher Education and and state for Scientific Research, and the Ministry of Local Development. As explained previously, the number of governorates participating in the questionnaire reached 22 governorates. Results of applying GICI to the Egyptian governorates are recorded in tables from (1) to (8) and figures from (4) to (8).

3.1 Innovation Performance of Governorates

In tables1,2 and 3, the innovation composite index along with its disaggregated inputs and outputs for each Egyptian governorate are shown. The value of the composite index ranged from 40 percent in case of Kafr El Sheikh governorate to 75 percent for Giza governorate. Giza succeeded to realise the best innovation value of input record (55 percent). This result is the outcome of both the performance of the factors producing innovation, and the enabling environment sub-pillars, which marked 53 percent and 69 percent, respectively. In most of Egypt's governorates, the composite innovation index exceeds 50 percent on the average. Four governorates recorded however an average performance that falls below 50 percent. These are Ben Sweef, Kalioubia, Red Sea and Kafr El Sheikh. Input measures to Egypt's governorate innovation index are generally limited (or having low performance). All governorates except Giza has a mean value less than 50 percent. Giza's performance accounts for 55 percent, whereas other governorates record performance values ranging from 18 percent in case of Matruh governorate to 48 percent in case of New Valley governorate. These results suggest then that the Egyptian government should revise its strategy towards more intensive supporting policies to enhance innovation inputs of governorates. Despite the delimited performance of innovation input sub-pillars, output pillars of most Egyptian governorates generate good results. Based on the outcome from the innovation composite index, the value of output aggregate pillar ranges from 53 percent to around 100 percent. From the 22 governorates, 16 governorates record indicators that exceed 80 percent, 18 governorates produce indicators that exceed 70 percent, and 21 governorates generate indicators that exceed 60 percent. On the other hand, more than 50 percent of the Egyptian governorates generates input performance measure that falls below 30 percent. In general, the deteriorating performance of innovation inputs is associated with the deteriorating measures of the factors of productions (composed mainly of innovative human capital and patent statistics). The set of inputs indicators contributing to the production of innovation output ranged from 6 percent to 53 percent. Furthermore, the performance of Egyptian governorates witnesses a differentiating nature with respect to the measures of the factors of production. On other front, private support to investors and households represents the best output performance measure of the Egyptian governorates. It exceeded other output Variables such as marketing, organisational and societal innovation. Finally, the innovation process of governorates has benefited from the appropriate enabling environment. This enabling environment is reflected in two sub-indicator which are international cooperation, and scientific coordination between governorates, and independent research centres and universities. More than half of the Egyptian governorates marks more than 50 percent with respect to the measured value of the enabling environment.

Table (1). Input and output pillars of the composite innovation index

	Composite Index	Innovation Inputs	Innovation Outputs
Giza	75.30	55.00	95.60
New Valley	70.51	46.89	94.13
Port Said	69.25	38.49	100.00
Suez	67.99	36.72	99.27
Aswan	65.36	32.19	98.53
Beheira	65.28	32.03	98.53
Sohag	64.72	32.23	97.20
Damietta	64.00	30.65	97.36
Menoufia	60.12	23.18	97.07
Sharkia	59.32	23.03	95.60
Dakahlia	58.77	30.81	86.73
Qena	58.51	28.74	88.27
North Sinai	58.39	18.99	97.80
Matruh	58.36	18.93	97.80
Gharbiya	56.14	32.66	79.61
Fayoum	54.11	20.32	87.90
Minya	51.85	22.77	80.93
South of Sinaa	50.71	24.53	76.90
Bani Sweif	45.11	23.22	67.00
Qaliubiya	42.38	23.62	61.13
Red Sea	41.98	22.46	61.50
Kafr El-Sheikh	40.69	27.57	53.80

Table (2) Innovation input Pillar and sub-pillars by governorate

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	Innovation Inputs	Enabling Environment	Factor of Production
Giza	55.00	59.16	53.22
New Valley	46.89	61.64	40.57
Port Said	38.49	77.73	21.68
Suez	36.72	37.38	36.43
Gharbiya	32.66	35.65	31.38
Sohag	32.23	90.10	7.44
Aswan	32.19	51.49	23.92
Beheira	32.03	65.35	17.75
Dakahlia	30.81	35.65	28.73
Damietta	30.65	65.35	15.78
Qena	28.74	50.50	19.42
Kafr El-Sheikh	27.57	49.26	18.28
South of Sinaa	24.53	61.64	8.62
Qaliubiya	23.62	41.10	16.13
Bani Sweif	23.22	39.36	16.30
Menoufia	23.18	37.38	17.09
Sharkia	23.03	48.52	12.11
Minya	22.77	59.16	7.17
Red Sea	22.46	60.65	6.09
Fayoum	20.32	39.36	12.17
North Sinai	18.99	35.65	11.85
Matruh	18.93	39.36	10.17

Table (3). Innovation output pillar and sub-pillars by governorate

	Innovation Outputs	Private Innovation	Organizational & Marketing Innovation	Societal Innovation
Port Said	100.00	100.00	100	100
Suez	99.27	98.17	100	100
Aswan	98.53	96.33	100	100
Beheira	98.53	96.33	100	100
North Sinai	97.80	94.50	100	100
Matruh	97.80	94.50	100	100
Damietta	97.36	93.40	100	100
Sohag	97.20	93.00	100	100
Menoufia	97.07	92.67	100	100

Giza	95.60	89.00	100	100
Sharkia	95.60	89.00	100	100
New Valley	94.13	85.33	100	100
Qena	88.27	70.67	100	100
Fayoum	87.90	94.50	50.5	100
Dakahlia	86.73	91.57	50.5	100
Minya	80.93	52.33	100	100
Gharbiya	79.61	98.53	100	50.5
South of Sinaa	76.90	67.00	50.5	100
Bani Sweif	67.00	67.00	100	50.5
Red Sea	61.50	78.00	50.5	50.5
Qaliubiya	61.13	52.33	100	50.5
Kafr El-Sheikh	53.80	34.00	100	50.5

3.2 Statistical Analysis of Results

In this section, a descriptive analysis is carried out to assesses the statistical parameters (such as the average value, the standard deviation, the maximum and minimum values) associated with the composite index as well as its pillars, sub-pillars and sub-indicators (Tables from 4 to 8 and figures from 4 to 8). The results reveal the following analytical points.
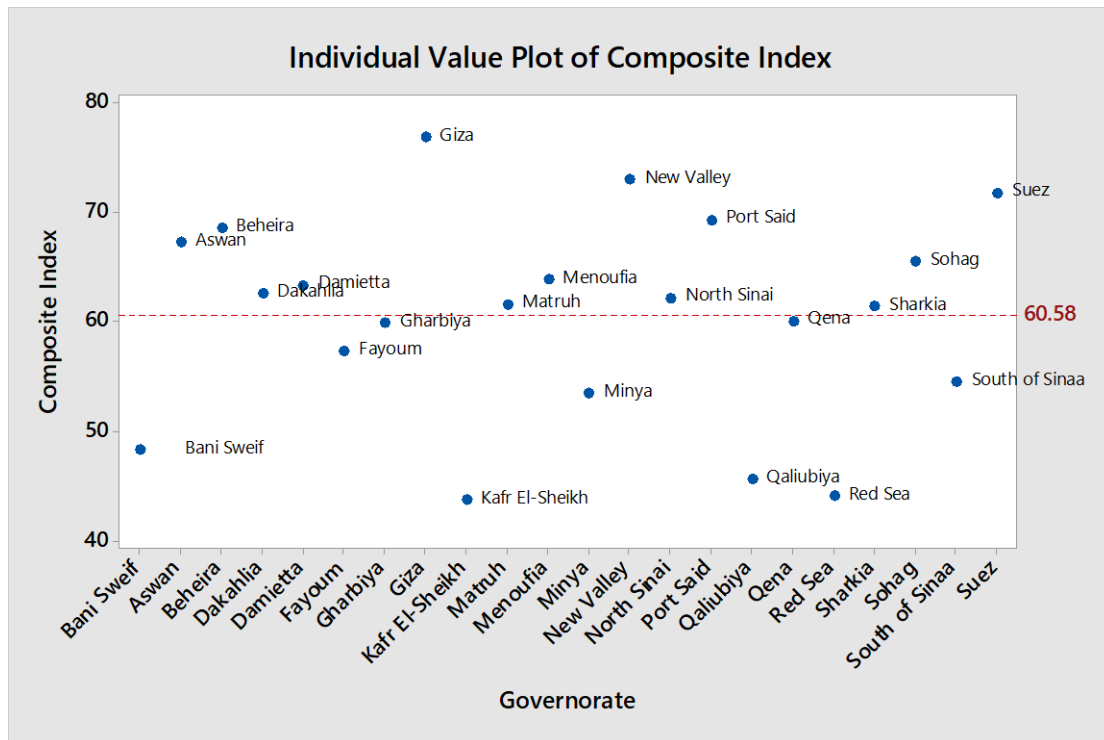
1. The statistics of the Egypt's composite index and its pillars are shown in table(4), whereas the scatter diagram of Governorates are schematised in figure(4). The mean value of the Egyptian governorate innovation composite index is around 61 percent, and the performance of Governorates ranges generally from 44 to 77 percent. This would suggest that the Egyptian governorate innovation performance is on the medium-high level. This result is confirmed by a low standard deviation (representing 1/6 of the mean value), which would suggest the increase of the degree of confidence in the obtained statistics.

2. Figure (4) shows the scatter diagram of the Egyptian composite index for the tested governorates. Despite the existence of some extreme points (such as Kafr-elsheikh and Giza governorates), the value of the composite index of governorates falls generally nearby, or around its average value, which is computed as 60.6 percent.

3. When the innovation composite index is divided into its inputs and outputs (as components of the innovation production function), different analytical results emerge. First, the mean value of innovation Outputs accounts for 87 percent, which is 20 percent higher than the average value of the composite index. The standard deviation of the output pillar is however on the high side (it represents about 62 percent of the mean value). This would certainly reduce the degree of confidence in the positive results of innovation output.

4. Compared to the output pillar, the mean of the innovation input pillar shows a decreasing trend. It does not exceed 35 percent on the average, which represents about half the mean value of the innovation composite index. This result stresses the need of the Egyptian government to adopt more intensive policy packages directed to enhance the innovation inputs in governorates. Furthermore, the scatter diagram of innovation input pillar by governorates (figure (6)) shows that 64 percent of the Egyptian governorates are located below the mean value of the pillar which reaches 34.2 percent. The only exception to this

finding is Giza and the new valley governorates. This result demands also an intensive analytical study to identify the causalities and reasons behind this deteriorating performance.

Table (4). Composite Index statistics – Innovation Inputs and Outputs

Variable	Mean	StDev	Minimum	Maximum
Composite Index	60.58	9.28	43.66	76.78
Innovation Outputs	86.94	53.80	53.80	100.00
Innovation Inputs	34.21	8.53	25.24	57.97

Figure (4) Composite Index Per individual Governorate

5. Table(5) divides the statistical measures pertaining to the innovation output pillar into private innovation support (directed to households and private investors), organisational and marketing innovation measures and societal innovation (broken down into innovation support for green economies and modernisation and development of the governorates infrastructure). The results are generally on the favourable side with a mean value reaching 89 percent, and a standard deviation that does not exceed 21 percent.

6. Given the particular features of the innovation process within governorates, societal innovation should play a more important role in achieving the desired goals. The average value of this sub-pillar is higher than the mean value estimate of the innovation composite index, as well as the innovative support to households and investors. This result coops then with the conceptual innovation rationale.

7. In table (6), the descriptive statistics of the breakdown of the innovation input pillar into sub- pillars are shown (factors of production and enabling environment). The statistical results confirm the deteriorating performance of the factors contributing to the production of innovation output, compared to the enabling environment. The mean value of the factors producing innovation does not exceed 19 percent with a relatively high variance of 12 percent (which represent 60 percent of the mean value). Given this considerable restricted performance, the science and technology policy maker in Egypt should adopt appropriate policy measures directed to enhancing innovation input capacity within governorate. Furthermore, the socioeconomic regional plans and sustainable development strategies need to trace this delimited performance over time. As expected, the enabling environment analytical indicators have shown generally sizeable impact on innovation with a mean value of 68 percent, and standard deviation that is limited to 10 percent.

8. In order to assess the impact of factors of production sub-pillar on Egypt's governorate innovation composite index (GICI), figure (7) decomposes this sub-pillar into its four sub-indicators. The creation of new (or significantly improved) technology-based industries, in support of establishing technology or business incubators and research valleys, has shown reasonable performance with a mean value of 52 percent. This improved performance is meanwhile negatively affected due to the increased standard deviation which represents 62 percent of its mean value. Descriptive statistics show, On the other hand, a clear shortage in providing other factors to generate innovation processes or products (goods and services).

Table (5). Decomposition of innovation output into sub-pillars

Variable	Mean	StDev	Minimum	Maximum
Innovation Outputs	86.94	14.39	53.80	100.00
Private Innovation	83.10	18.17	34.00	100.00
Organizational & Marketing Innovation	91.00	19.54	50.50	100.00
Societal Innovation	88.75	21.23	50.50	100.00

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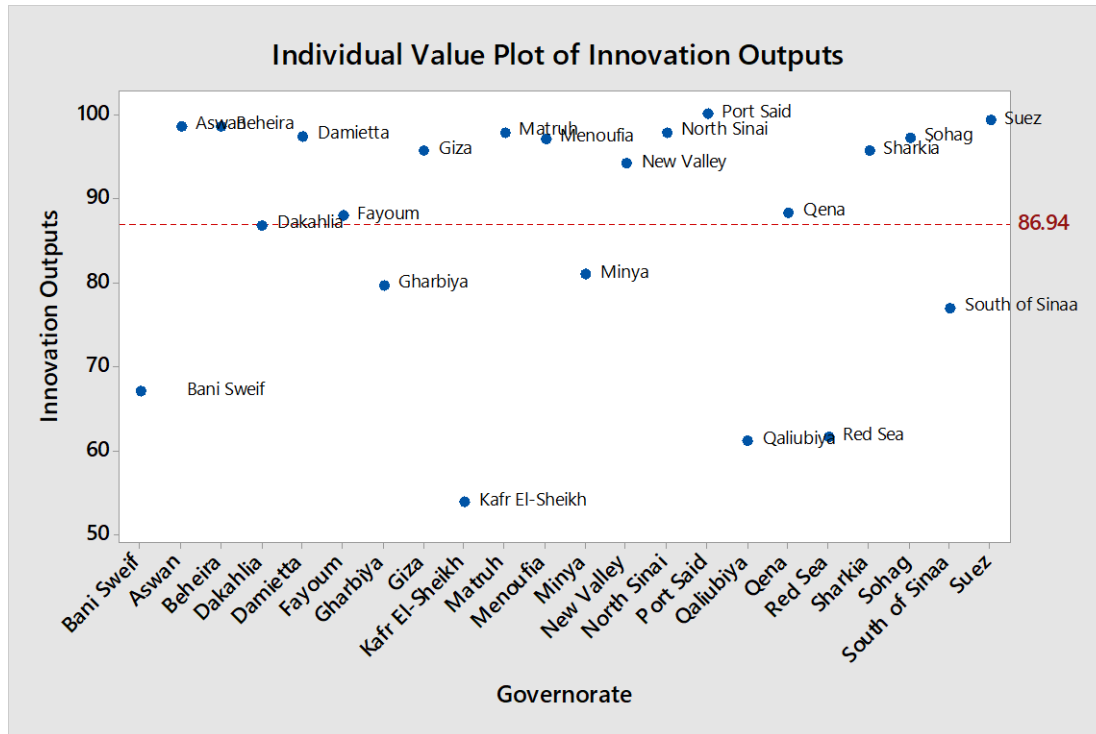@Entrepr69728810

Figure (5). Innovation output Pillar per Governorate

9.   The sub-indicator related to the establishment of new (or significantly improved) small and medium size industries reflects in a way, the supporting policies of innovation to the production sphere of the economy. These statistics produce the lowest performance measure which is around 15 percent. Furthermore, its standard deviation exceeded 100 percent of its mean value of performance. Given the growing role of innovation in production activities to achieve economic growth, improve welfare of citizens and satisfy sustainable developed strategies (based on the recommendation of OECD and UNESCO international organisations), appropriate policy measures are strongly needed to address this specific innovation area.

10.   Patent statistics is another factor of producing innovation outputs in the Egyptian innovation composite index. Patents are viewed as an important, as well as practical step, towards developing an innovation product or process. A patent application, if properly financed, can produce a new or significantly improved good, service or process that can be commercialised in the economic markets as an innovation outcome. The sub-indicator of patent statistics for innovation in the Egyptian governorate composite index (GICI) generates low performance measures with a mean value of 27 percent and standard deviation of 21 percent (about 78 Percent of the mean value). This law average value with relatively high standard deviation measure stresses the need for intensive policy measures from Egypt's government to support the development and application of patents.

11.   Based on international practice and empirical evidence, innovation output cannot be properly produced without skilled, competent and highly educated and trained work force. These knowledge workers are generally needed to form the innovation human capital. Furthermore, human capital development is considered also as a major factor for transforming countries to the knowledge Economy and achieving sustainable development objectives. The collected statistics relevant to the human capital in case of the
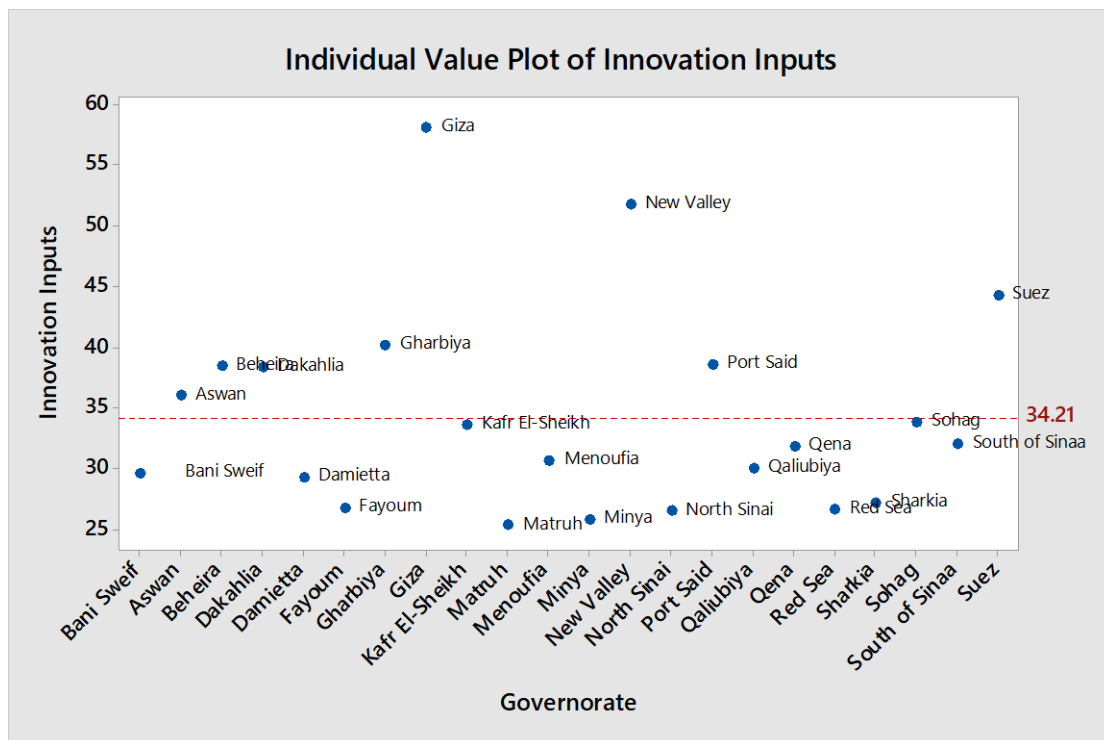
Egyptian governorates' innovation index suggest that considerable effort is still needed in this area. Based on the statistical results, the mean value of the human capital measure is only 27 percent, whereas the standard deviation represents 74 percent of this mean value.

12. Table (8) summarises the descriptive statistics of the enabling environment sub-pillar. The enabling environment in the Egyptian governorate innovation composite index is represented by the cooperation with the organisations of the outside world, and the cooperation between the governorate and research centres and universities.

Table (6). Decomposition of innovation inputs into sub-pillars

Variable	Mean	StDev	Minimum	Maximum
Innovation Inputs	34.21	8.53	25.24	57.97
Enabling Environment	68.20	10.36	60.40	95.05
Factor of Production	19.65	11.98	6.09	53.22

Figure (6). Innovation Input Pillar Per Governorate

Table (7). Factors of production sub-pillar and its decomposition

Variable	Mean	SD	Minimum	Maximum
Factor of Production	19.65	11.98	6.09	53.22
Technology Based Industries	52.75	32.32	1.00	100.00
New Small/Med Industries	15.21	17.56	1.00	53.93
Patents for Innovation	24.81	21.00	1.00	100.00
Innovative Human Capital	26.79	19.48	1.00	66.68

Table (8). Decomposition of the Enabling Environment

Variable	Mean	StDev	Minimum	Maximum
Enabling Environment	68.20	10.36	60.40	95.05
Cooperation with Research Center	61.64	14.81	50.50	100.00
International Linkages	83.500	0.000	83.500	83.500

The mean value of the estimated enabling environment ranges from 62 to 83 percent with a standard deviation that does not exceed 17 percent of the mean value of the indicator. In fact, the openness of governorates to cooperation with outside world and their reliance on technical support provided by research centres and university represents a favourable policy measure characterising the knowledge era and contributes to the characteristics of the industrial revolution of the twenty one century.

4. Conclusion and Policy Recommendation

Innovation is becoming today a major factor in support of science and technology policies and the transformation towards knowledge society and economy. Innovation accelerates economic growth and improves welfare measures of citizens as part of the sustainable development strategy of a country.(Alsan 2016, Bassinini et al 2000,, Pessoa 2010, OECD 2004 and 2010, EBRD 2019, Khorshid 2018, Khorshid and Ismail 2019, Ulku 2004). Based on recent worldwide indicators, innovation is considered a prerequisite for transforming countries to knowledge-based technology- advanced digital economy. The innovation process is generally represented by a multidimensional model composed of ; (i) alternative sources (or institution) producing innovation products or processes, (ii) different application domains of innovation and (iii) alternative type of output generated by the innovation process. Innovation can be for example, generated in research centres or universities, developed in manufacturing or services business sectors, created by society at large. On the other hand, innovation can be assessed considering the domain of application (economic versus social domain). Finally, innovation can be developed based on alternative output forms. This classification can include knowledge and technology outputs, creative and culture industries, and intangible assets.

Given its extended worldwide impact on sciences, technology, knowledge and sustainable development , innovation should be estimated on a frequent bases to determine its development stage and extended impact. Innovation statistics need however to consider four development issues; (i) a conceptual design reflecting the analytical objectives of the composite index, (ii) an innovation production function composed of inputs and

outputs, (iii) an enabling environment broken down into socioeconomic, cultural, institutional and physical infrastructure, and finally (vi) advantages, limitations, impact and scope of application.

In this paper, a special composite innovation index is designed, estimated and applied to the Egyptian case. The Egyptian governorate innovation composite index (GICI) is primarily used to assess the innovation performance on the regional or governorate level. It is decomposed into aggregate input and output pillars representing the components of its production function. Inputs include both factors of production and enabling environment (inputs sub-pillars), whereas outputs are broken down into innovation support to households and private investors, marketing and organisational innovation, and societal innovation.

Results of applying the composite innovation index to the Egyptian governorates reveal a number of analytical points and a set of policy recommendations. The performance of governorates measured by the value of the innovation composite index, shows a moderate attitude. The mean of the composite index ranged from 40 percent in Kafr El Sheikh governorate to 75 percent in case of Giza governorate. The mean value of the innovation composite index across governorates is 60.6 percent, and the standard deviation accounts for 9 percent (or 15 percent of the value of the mean statistic). Giza succeeded to achieve the best mean performance with respect to the set of inputs of the innovation production function, which is estimated as 55 percent. This result applies to both the factors of production and the enabling environment (53 and 59 percent respectively). The mean value of the input sub-pillars for other governorates are generally on the low side. Its The mean value across governorates does not exceed 35 percent. Furthermore, their maximum value accounts respectively for only 58 percent, which does not represent an acceptable result. In light of this finding, Egypt's government needs to consolidate efforts towards enhancing the capacity of innovation inputs, with special reference to the components of the innovation production function.

Despite the restricted or delimited results of innovation input sub-pillars, the mean value of the output pillar of most Egyptian governorates generates good statistics. The mean value of the governorates output pillar ranged from 53 to 99 percent on the average. Furthermore, 16 from the 22 governorates generated a mean value of indicator that exceeds 80 percent. It is noted also that innovation support to households and investors represents the highest performance measure of the output pillar. On other front, more than 50 percent of the Egyptian governorates has generated input performance measure that falls below 30 percent. Based on this rationale, the Egyptian government needs to adopt an integrated policy package directed to reduce the difference in performance between governorates on one hand, and achieve the balance between input and output support for all governorates on the other hand.

In principle, the innovation composite index on the regional or the governorate level is characterised by two distinguishing features; the importance of societal innovation statistics, and the emergence of the enabling environment. Science and technology policy makers should in this respect devote particular attention to these two issues in designing the composite index, when moving from the micro level (a company, an organization or a production activity), to a regional or national level. Both the enabling environment and societal innovation in case of the Egyptian governorates, generated mean values ranging from 68 to about 89 percent, with low standard deviation ranging from 10 to 19 percent. This good performance suggests then that the generation process of innovation, and the relative importance of its statistics are considerably affected by the scope of application (a production unit, a service business, an economic sector, a region, or a country at large).

Based on empirical evidence and analytical studies done by UNESCO and OECD organisations, a production activity (producing goods and services) represents an important source of generating innovation products and

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processes. In the Egyptian governorate innovation composite index, this dimension is represented in the sub-indicators concerned with the support to advanced technology based industries(composed generally of research parks and business incubators), and the establishment of new small and medium enterprises (SMEs). Although high technology industrial innovation sub- indicator performed properly (with an mean value of 52 percent and a standard deviation of 32 percent), the support to new modern small and medium industries (SMEs) for innovation needs however additional enhancing policy measures from the government of Egypt(the mean value was less than 16 percent and the standard deviation accounted for 17 percent).

The estimated input statistics suggest that the innovative human capital and patent statistics do not receive appropriate support from the government of Egypt. Their measured mean values were 26 and 24 respectively, with relatively high standard deviation of 73 percent and 88 percent of their means, respectively. Given the importance of these factors of production in generating innovation products and processes, further policy measures are still needed in this respect.

It should be noted finally that this paper tried to capture the distribution of innovation efforts, efficiency and effectiveness among the regions (or governorates) of Egypt. The paper suggests that the difference in innovation performance between governorates should be considered as an important factor in developing national science and technology strategies and innovation national plans as well as their economic impact. Up to the authors knowledge, studies concentrating on the analysis of the regional dimension of innovation are up till now, limited to a great extent.

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