An overview on the Algerian National Innovation System in the digital era

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Abstract:

The Algerian National Innovation System (NIS) is being discussed, its structure, key actors, role and the main challenges it is experiencing before and in the context of digital transformation. We intend to reveal the major characteristics of Algeria's NIS, as well as the impact of digital technologies on its performance, in order to highlight the challenges confronting it and the efforts required to overcome them. The Algerian NIS remains in its early stages and will need additional efforts from all its actors.

Key words: National Innovation System, Industry 4.0, Digital Transformation, Innovation, Knowledge.

JEL Classification Codes : I25, M15,O14,O31,O32,O33.

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Introduction :

The world is witnessing a drastic shift in term of technology usage under the concept of "Digital Transformation" which is also known as "4th Industrial Revolution" and 'Industry 4.0' (Lasi et al., 2014; Schwab & Sala-i-Martín, 2016). this technical change and the introduction of Industry 4.0 technologies is the primary engine for economic development, through the innovation process that depends on the accumulation and treatment of relevant knowledge(Han, Pang, & Manfred, 2001). These technologies break the boundaries of organizations to be more open to other actors and ready for knowledge sharing and innovating together as part of a national innovation system. The purpose of this paper is to provide elements of response to the following research question:

What are the main challenges that the Algerian National Innovation System faces in the digital transformation era, and how can they be overcome?

The following is the format of our paper. First, we presented a literature review, focusing on the most important studies that describe Algeria's national innovation system. Second, we presented the impact of digital transformation and I4.0 digital technologies on the Algerian economy in general and its NIS in particular by evaluating its main indicators. finally, based on the findings, future directions for improving the functioning of the national innovation system in order to effectively embed Industry 4.0 are proposed.

1. Theoretical foundations of the national innovation system:

1.1.The different definitions of national innovation system

A National System of innovation "NIS" has no single accepted definition (Manning, Turkisch, Ketelaar, Manning, & Turkisch, 1995, p. 10):

"*.. the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.*" (A Myrick Freeman, Freeman, & Freeman, 1987) "*.. the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge ... and are either located within or rooted inside the borders of a nation state.*"((Lundvall, 1992) "*.. a set of*

institutions whose interactions determine the innovative performance … of national firms." (Nelson, 1993)b"*.. the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country*." (Patel, Pavitt, & technology, 1994)b"*.. that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies*." (Metcalfe, 1995)

2. Analysis of the Algerian National Innovation System (NIS)

We retain the definition of Freeman (1988) already prevails in the south, it defines NIS as "institutions of networks in the public and private sectors whose activities and interactions initiate, import modify and diffuse new technologies these institutions are not only those directly responsible for research and development activities, but also how resources are managed and organized, both at company level and at national level" (Freeman, 1972).

The analysis of empirical work on the NIS shows that there are a variety of indicators to assess a NIS. They are divided into three categories (Niosi, Faucher, National Competitiveness: Oligopoly, & Competition, 1991). The first category measures the factors, namely the number of innovative organizations (universities, laboratories and research centers, companies doing R&D), size and governance and finally their degree of concentration. The second category evaluates flow. These technology flows, financial (public or private), social, people (between universities and companies or between companies), commercial, legal and political. The third and last category measures the performance through scientific performance indicators (scientific papers) and technological (number of patents), and also though the balance of imports and exports in high-tech goods and services.

2.1. Assessment elements

2.1.1. The institutions and research infrastructures

In Algeria the National innovation and research system is constituted of 91 establishment and research center all sector confounds, among which:

- Sixty-nine (69) of higher education establishment (universities, universities centers and national higher schools) .
- Twelve 12 centers of research of MESRS.
- Ten (10) Research centers and institutes out of MESRS.

Despite of this complete institutional structure, the national system of research still weak. A weak mobilization of permanent researchers, which necessitate an effort to enhance that (DGRST, 2018). In 2018, the activity of patents of national researchers attains 275 patents by 31 December 2018, in 2016-2017, it was 237 which illustrates a weak dynamic in research institute and centers (DGRSDT report 2018) (figure 1)

Figure N° 1: Number of patents in Algeria issued by DGRDT

Source: (DGRSDT, 2018)

2.1.2. The scientific and technical personnel

In Algeria, the number of labs, researches, research teacher, Doctorates (PhD students) is as follows in table 1.

Table N° 1: number of Researcher, labs, teacher researchers, doctorate by domain in 2018

Domain	Number of labs	Number of researchers	Number of teacher researcher	Number of doctorates (PhD Students)
Human and Social Science	525	16761	11933	4828
Hard Science	915	32243	21690	10553
Others		4583	1103	3308
Total	1440	53587	34726	18861

Source: (DGRSDT, 2018)

The number of researchers and financing resources mobilized by R&D have known a positive evolution last years, these indicators are not translated in the GII Index and absent in the UNESCO Data, which show and prove a lack of information dissemination (DGRSDT, 2018)

3. Evaluation of flows

There exist several ways to measure innovation, but the most used measures are known as the traditional measures of innovation, which are R&D expenditures and patents, although R&D it is not the only source of innovation (Encaoua, Guellec, & Martínez, 2006) the fact remains that R&D is at the heart of the innovation process.

3.1.Research and development expenditures

Gross Domestic expenditure on R&D (GERD) (GII, 2020), is mainly used as aggregate for international comparisons. In Algeria, the objective of the law of research in 1998 has been allocated a budget of 1% of GDP for scientific research, but according to Global Innovation Index Report, this percentage is more optimistic than the reality, where the GERD of Algeria is about 0.5% (GII Report, 2020). Even though, we see some efforts done by the DGRSDT (Direction générale de la Recherche Scientifique et du Développement Technologique). DGRSDT devoted 6 billion DZD in equipment for new infrastructures underway of reception, and 1 billion DZD for maintenance of infrastructures and scientific equipment. Also, a 200 million DZD expected to finance Scientific mobility and activities. (DGRSDT Report, 2018)

4. Evaluation of performance

The performance of innovation is measured directly and indirectly at a national level. The calculation of patents by researcher, or patents by millions of dollars spent are used as indicator of the NIS productivity and innovation performance.

4.1. Scientific production of Higher Education and research sector publication and citation ranking

Based on the SJR ranking (Table 2), Algeria comes in the 58th position from a 241 ranking country where we can see the evolution of cited documents from 1996 until

2020, we see that USA preside the list with an important H index and ranked in the first place, this ranking of publications in all subject areas.

Table N° 2: Country ranking based on SJR (1996-2018) and in 2018

Rank	Country	region	documents	Citable documents	Citations	Self-citations	Citations per document	H index
1	Usa	North America	13 817 725	11 986 435	384398099	168230420	27.82	2577
5	Tunisia	Africa	104541	98601	1027585	195274	9.83	214
8	Algeria	Africa	84192	80961	725764	146594	8.62	202
9	Morocco	Africa	83349	77388	794014	154494	9.53	222

Source: available on: https://www.scimagojr.com/countryrank.php?region=Africa †

4.2. Number of publications by millions of residents and number of publications by researcher

Algeria is far of standard, with 157 publications by million residents in comparing with other countries, for example, Switzerland classes in the 1st position with 5000 publications by million residents, this witnesses an economy essentially based on the human capital. The evolution of scientific production of Algeria from 2000 to 2016, all disciplines confound (Table 3)

Table N° 3: Number of scientific publications per population per year in Algeria

Year	Numbers of publication	population in millions of residents	Number of publications per million of resident
2000	**524**	**31.18**	**16**
2008	**2477**	**34.6**	**71**
2012	**4287**	**37.5**	**114**
2014	**5278**	**39.1**	**134**
2016	**6544**	**40.6**	**157**

Source: (DGRSDT, 2018)

† Available on : https://www.scimagojr.com/countryrank.php?region=Africa consulted : 14/12/2021

4.3. Technological production

In emerging innovation systems, firms are not yet able to produce radical innovations, but they are accumulating the competences and capabilities that are needed to engage in different forms of interactive learning and innovation (Chaminade, Lundvall, Vang-Lauridsen, & Joseph, 2009). Technological capabilities the ability to make effective use of technological knowledge is called technological capability (Westphal, Kim, Dahlman, Rosenberg, & Frischtak, 1985)do not only allow firms to choose and use technology (Aeron & Jain, 2015; Gomel & Sbragia, 2006) but also to create new methods, processes, techniques and products (Afuah, 2002; Zhou & Wu, 2010). This occurs as knowledge adoption generates a learning process through which firms internalize new knowledge and get involved in R&D and innovation activities (OECD, 2005). Innovators deposed 3.17 million demands of patent in the world in 2017, which represent a rise up of 5.8% in comparison with the year 2016. For Algeria, Data are not published in the edition of 2018 (figure 2) and that's for all industrial property titles which refers to a lack of e-participation of the Algerian government.

Figure N° 2: Patent applications by Office and Origin, 2017

Name	Applications by office			Equivalent applications by origin	PCT international applications		PCT national phase entry	
	Total	Resident	Non-resident	Total [+]	Receiving office	Origin	Office	Origin
Afghanistan (b)	..	..	..	28	n.a.	0	..	4
African Intellectual Property Organization	519	105	414	n.a.	3	n.a.	400	n.a.
African Regional Intellectual Property Organization	747	17	730	n.a.	1	n.a.	701	n.a.
Albania	24	..	..	2	1	7	..	1
Algeria (b)	..	..	..	14	10	12	..	3
Andorra	6	0	6	42	n.a.	5	..	28

(b) The office did not report resident applications, therefore, the equivalent applications by origin data may be incomplete.

.. Indicators not available

Source: World Intellectual Property Indicators 2017, WIPO Statistics Database.

In a survey done by DGRSDT in 2018, the tables below show the activity of patents of national researchers that attains 275 patents in 31 of December, and 237 in 2016-2017

Table N° 4: Number of invention patents of national researchers (31/12/2018)

N°	Higher Education and Formation Institutions & Units and Research Centers	Number of Patents
01	Higher education and research establishments	134
02	Research centers and units MESRS	107
03	Research centers and Institutes outside MESRS	27
04	Research Agencies MESRS	07
Total of brevets		275
Number of brevets deposited by Algerian community a broad		2812

Source: (DGRSDT, 2018).

5. Digital Transformation in literature

The world is witnessing a drastic shift in term of technology usage under the concept of "Digital Transformation" which is also known as "4th Industrial Revolution" and 'Industry 4.0' (Lasi et al., 2014; Schwab, 2017). Industry 4.0 (I4.0) has been referred as the new industrial paradigm that will possibly lead companies to superior performance results through an extensive adoption level of novel information and communication technologies (Lasi et al., 2014). Different countries around the globe are introducing I4.0 plans to support the adoption of new digital and connected technologies by firms, especially among SMEs. The table below show some international cases. The term "Industry 4.0" officially introduced by the German Promoters Group of the industry-Science Research Alliance in 2011 (Kagermann, 2015)). It was the first strategic initiatives at national level to foster the digitalization of manufacturing ("smart factories") willing to enhance the interconnection of products, value chains and business models, the collaboration between academia and enterprises, and among the German companies (European Commission, 2017). It is described as the digital transformation of industrial value chains in their totality (Culot, Nassimbeni, Orzes, & Sartor, 2020), a rapid development of societies and industries around digitalization, connectivity, and automation describing the new industrial revolution,

also known as industry 4.0 by a new wave of technological innovation (Ghobakhloo, 2018; Kagermann, 2015; Lasi et al., 2014) . After Germany, the Usa introduced the Advanced Manufacturing Partnership in 2012. Other countries followed year after year, we see France in 2015 proposing its Industry 4.0 named as Industrie de Futur. As an alternative, Italy was one of the last countries to propose its governmental program Industria 4.0 (Piano Nazionale Industria 4.0) in 2016, which was adopted the following year (Lepore & Spigarelli, 2020). To the best of our knowledge, we have found no official documents of "Industry 4.0 plan" for Algeria designed by the government or the ministry in charge of ICT adoption and promotion, except few reports conducted on the private scale by consulting firms or private institutions. However, governments remain important actors in both policy development and enforcement by identifying governance protocols for introducing new technologies (World Economic Forum, 2017), which is unfortunately not the case in Algeria.

Table N° 5: Industry 4.0 plans around the world

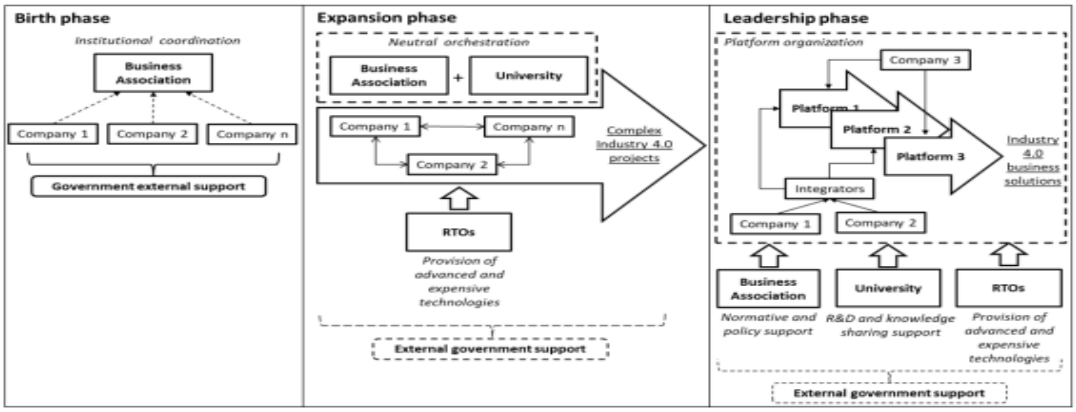
Country	Plan	Year
Germany	**Industrie 4.0**	**2011**
USA	**Advanced Manufacturing Partnership**	**2012**
France	**Industrie de futur**	**2015**
Italy	**Piano Nazionale Industria 4.0**	**2017**

Source: adapted from (Lepore & Spigarelli, 2020)

According to the study of Guilherme et al.,2020, it helps to obtain a broader understanding of the evolutionary aspects of Industry 4.0 ecosystems and the different relationships among companies and actors. The figure below summarizes the evolution of relationships which we can replicate in the national innovation system since the same actors in the figures are involved (universities, firms or companies and government). According to the data on the Algerian national innovation system, we can assume that it is in the birth phase. Where it is described by a weak relationship between companies and universities. According to the authors, at this stage, companies were oriented

toward a linear supply chain model where each industry 4.0 technology is exchanged as a unit with other companies. Also, the government acted as an external supporter, providing funds for the consolidation of the business association.(Benitez, Ayala, & Frank, 2020)

Figure N° 3: Structure of the industry 4.0 ecosystem in each lifecycle stage



Source : adapted from (Benitez et al., 2020)

In order to move to the other stage, it necessitates a better orchestration between the business association and the university. In the case of Algeria, we have seen a very timid number of patents and less interaction between universities and companies in terms of worker mobility and the possibility to work in both domains at the same time due to some issues in regulation contracts.

6. Linking Algerian NIS and the digital transformation

This section will focus on the possible repercussions of digital transformation at various levels, namely micro and macro levels, in a policy context. We have identified some key indicators related to the performance of Algerian NIS in the industry 4.0. The Algerian economy ranks 53rd in the 2019 list of world economies with $759.480 billion of value total Gross Domestic Product at current prices (Bank, 2021) . The country has a population reached 44.2 million inhabitants and comprises 26.3 million internet users and 25 million of social media users. There are 59.6% of the population are connected and only 4.6% of that makes online purchases or bill pay, despite the fact that the vast majority preferred the cash on delivery method for e-commerce. With an online payment usage is rising fast to reach 638k transactions and 5.4 billion DZD in volume in

2020 (224.81% CAGR over 5 years) (GIE Monetique, 2020‡) .by the end of 2018, making it the second-largest country in North Africa after Egypt. A young population with a median age of 27.8 and 29.2% of residents under the age of 15. Algeria is classed as an upper-middle income country. Algeria's GDP is anticipated to reach $488.3bn by the end of 2021. Its per capita GDP, anticipated to reach $11,041 by the end of 2021, indicates that it has the highest living standards in the Maghreb. Tunisia and Morocco follow with per capita GDPs of $10,382 and $7,609, respectively. (GII, 2021)

6.1- Coverage and connectivity

This is due to issues related to connectivity and mobile broadband coverage (3G above). The coverage gap remains significant in Africa, where, despite a 21 per cent increase in 4G coverage since 2020, 18 per cent of the population remains without any access to a mobile broadband network (figure below).

Figure N° 4. Population coverage by type of mobile network, 2021

Note: The values for 2G and 3G networks show the incremental percentage of population that is not covered by a more advanced technology network (e.g. 95% of the world population is covered by a 3G network, that is 7% + 88%).

Source: ITU (International Telecommunication Union), 2021.

Algeria's plan to extend further submarine cables (fiber optics) to Spain, Niger and Nigeria. According to the Huawei Global Connectivity Index§, Algeria is ranked

‡ Available on : https://giemonetique.dz/qui-sommes-nous/activite-paiement-sur-internet/ consulted : 14/12/2021

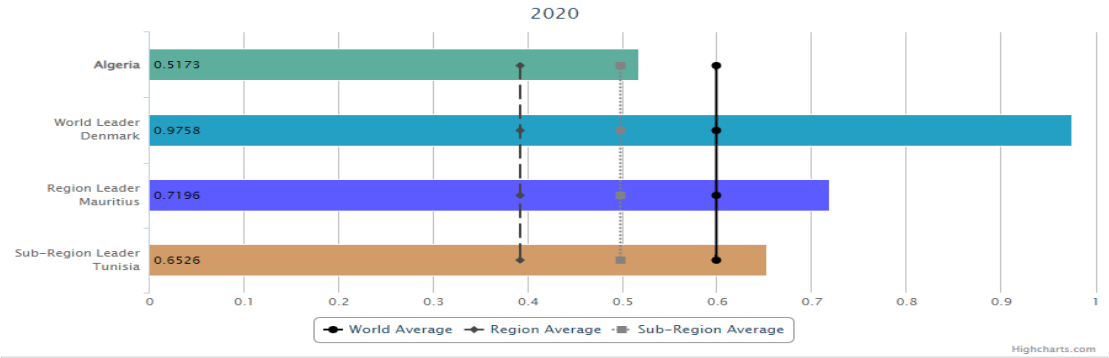
§ Available on : https://www.huawei.com/minisite/gci/en/country-rankings.html consulted : 15/12/2020

69th/79 in 2020, while Morocco is ranked 60th/79 with scores of 32/120 and 38/120, respectively

6.2- The e-government development index

Many countries are pursuing digital government strategies, some of which are radically different from the ones guiding earlier e-government initiatives. Some of these approaches include the delivery of e-government as a platform, the integration of online and offline multichannel delivery, the agile development of digital services, the expansion of e-participation and partnerships, the adoption of data-centric approaches, the strengthening of digital capacities to deliver people-centric services, and the innovative use of new technologies such as artificial intelligence (AI) and blockchain, especially in the development of smart cities. In the Un E-Government Survey 2020, Algeria moved up 10 positions to 120th place compare to 2018 in the e-government development index measuring online service, telecommunications infrastructure and human capital for the 193 UN member states.

Figure N° 5: The E-Government Index



E-Government Development Index	2020	2018	2016	2014	2012	2010	2008	2005	2004	2003
Algeria (Rank)	120	130	150	136	132	131	121	123	118	91
Algeria (Value)	0.51730	0.42270	0.29991	0.31064	0.36077	0.31810	0.35150	0.32423	0.32476	0.36993

Source: Publication of UN, 2020.**

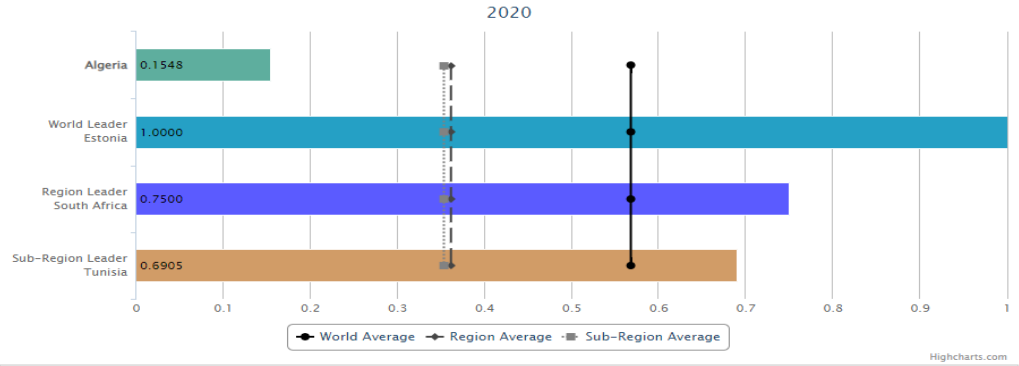
In the case of Algeria, there was an improvement in its rank from 2016 to 2020. And it reaches the region's average but is still behind the sub-regional leader: Tunisia.

6.3- The e-participation index

** Available on: https://publicadministration.un.org/egovkb/en-us/Data/Country-Information/id/3-Algeria Consulted: 15/12/2021.

Participation is a key dimension of governance and one of the pillars of sustainable development. The 2030 Agenda for sustainable development highlights the importance of participatory processes. The publication of information is almost universal, with more than 170 countries publishing some kind of information in each of the six sectors considered (health, education, employment, social protection, environment, and justice). The e-participation of governments includes the provision of information. The case of Algeria is shown in the figure below:

Figure N° 6: The E-Participation Index



E-Participation Index	2020	2018	2016	2014	2012	2010	2008	2005	2004	2003
Algeria (Rank)	183	165	167	172	124	157	152	105	97	91
Algeria (Value)	0.15480	0.20220	0.11864	0.07843	0.05260	0.01428	0.02272	0.03174	0.03278	0.05170

Source: Publication of UN, 2020. [††]

From 2003 to 2020, Algeria had a low and recessive rank compared to the sub-regional leader: Tunisia. In the matter of funding innovation, in the Algerian case, there are +900 start-ups identified, of which +40 have been granted the government's Startup label. The main problem with startups in Algeria is funding. The ANSEJ programs are said to have become a political instrument used to buy social peace. Indeed, although aiming at fostering entrepreneurship among youth, they are heavily criticized for lacking appropriate accompanying measures. The Algerian government created a dedicated ministry for "knowledge Economy and Startups" and also dedicated an online platform to start-ups (https://stratup.dz/), a special fund which is the "Algeria Start-up Fund" and also a "Start-up Label" granting tax benefits to eligible companies. Algeria is ranked 75th in ICT access and 76th in ICT use. (GII, 2020)

[††] Available on: https://publicadministration.un.org/egovkb/en-us/Data/Country-Information/id/3-Algeria Consulted: 15/12/2021

Table N° 6: Funded Projects in the ICT sector

	Total of funded projects	Funded project in ICT	Rate %
Since foundation to 12/31/2010	140 503	6 858	5%
2011	42 832	451	1%
2012	65 812	616	1%
2013	43 039	591	1%
2014	40 856	591	1%
2015	23 676	655	3%
2016	11 262	750	2%
Since foundation to 12/31/2016	367 980	10 549	3%

Source: adopted from (www.ansej.org.dz)

Encouragement for the development of high quality, innovative projects that generate added value (ICT and Startup) through a specific accompanying measurement dedicated to university graduates has allowed for an increase in the proportion of funded projects in the ICT sector from 2% in 2014 to 3% in 2015 and 6% in 2016.

7. Opportunities, Challenges and Recommendations

Based on the different data gathered and analyzed, we have developed the following key recommendations and future directions to accelerate the Algerian economy's fourth revolution in general and to improve the efficiency of its National Innovation System in particular.

The population in Algeria is characterized by large number of tech-savvy and young, connected individuals, which gives them the prerequisite for fast learning and the best and most adapted education in digital technologies. A better education should be planned including a new syllabus and innovative ways of teaching, and should also accompany businesses and individuals adopting digital services. The government needs to focus on digitalization and the start-up industry, by providing support for ICT producers, notably through better access to funding and talent formation, by

developing a mechanism of accompanying and financing digital project holders like venture capital and business angels' activities, and should also implement a digital agenda and review existing laws and regulations impeding the development of a digital economy and set plans for investment in modernizing the technical and payment infrastructure of the country. In addition, Encourage Fintech and enhance retail access to financial services, digitalization of purchases, businesses and financial products will expedite financial inclusion.

The Algerian government should adapt the current laws and regulations to meet the new requirements of industry 4.0, review and reform those who impede digital entrepreneurship (copy-right law, self-employed status, the management of websites, e-signature, and digital identity). Therefore, to promote digital activities, the government must review the tax laws to encourage digital initiatives. The data must be secured through the building of a cloud infrastructure that hosts local websites and protects the sensitive data of the population.

The education sector must be reviewed. It must include a special diploma to create the next generation of soft and hard skills related to industry 4.0 technologies. However, there are essentially no links between industry and academia. A considerable effort will be required to develop appropriate structures and job positions.

The policy of patents in Algeria does not encourage researchers either to deposit their patents or to exploit them, due to the unfamiliarity with the system of patents, technical constraints such as (lack of specialists in patent drafting and the weakness of the structure in charge of proceedings deposits) and also the timid reward incentives for these researchers due to a weak legal framework to regulate patents. Weak relationship of cooperation between universities and enterprises, that is just explained by final year research project, as an example, engineering theses, master theses, PhD theses…etc. explained by the low confidence of enterprises in projects done by researchers in universities, and low engagement in innovative projects that cost too much and whose reward is not sure and not immediate, which does not match with enterprises' expectations.

The use of digital technologies is growing on a fast pace in Algeria, for many people, connectivity is either unavailable or unaffordable, government need to hasten network deployment and address affordability issues.

Conclusion

The transformation into a knowledge-based economy is important for Algeria in order to achieve sustainable long-term economic growth and realizing the vision of becoming a developed country by 2030. This present paper tried to discuss the National Innovation System in Algeria, being a less developed country and facing the major problem of only depending on oil and gas exportation, it demonstrates the embryonic state of Algerian NIS. It presented the particularity of being incomplete showing disconnections between the economic sectors, universities and research institutions. Thus, it hinders its functionality and efficiency, especially in the era of digital transformation and massive shifts to industry 4.0. yet, these interactions are essential to the process of learning and knowledge creation, which are linked directly to the technical progress and economic performance.

The NIS play an eminent role in facilitating the adoption of Industry 4.0 technologies. The establishment of an" Industry 4.0 plan" for Algeria can strengthen the knowledge base of its national innovation system, thus, promote the shifts towards Industry 4.0 objectives.

Finally, more research on the Algerian NIS in the era of industry 4.0 should be further investigated by scholars and taken into consideration by the concerned institutions.

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