Fourth Industrial Revolution

Impact of the Fourth Industrial Revolution on Development in the Arab region

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Economic and Social Commission for Western Asia

Impact of the Fourth Industrial Revolution on Development in the Arab region

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موجز تنفيذي

يستعرض هذا التقرير المناقشات التي تناولت الثورة الصناعية الرابعة في سياق البلدان العربية. وتدعم اللجنة الاقتصادية والاجتماعية لغربي آسيا (الإسكوا) البلدان العربية في هذا المجال من خلال إتاحة المعارف ذات الصلة، وعقد اجتماعات بين الجهات المعنية في المنطقة، وتقديم المشورة الفنية في المجالات المتعلقة بسياسات تكنولوجيا المعلومات والاتصالات وتتبع هذه التكنولوجيا وإدارتها، وباستراتيجيات الابتكار وسياساته وبناء المؤسسات ذات الصلة. وقد عملت الإسكوا، خلال ما يزيد على عقدَين من الزمن، على تعيين التكنولوجيات الحيوية، وتنظيم اجتماعات تركز على التكنولوجيا، وإعداد تقارير في هذا المجال دعماً لتطور القطاعات الصناعية في البلدان العربية. وقد شهد العالم تطورات تكنولوجية سريعة منذ عام 2016، بفعل الاتصالات الفائقة السرعة والميسورة الكلفة، والحوسبة القوية، والخدمات السحابية والتخزين السحابي لعدد هائل من البيانات. وقد أدت هذه التطورات إلى اعتماد منظومة الأمم المتحدة عدداً من التكنولوجيات الرائدة والرقمية، لما لها من دور أساسي في تسريع تنفيذ أهداف التنمية المستدامة، على غرار البيانات الضخمة، والذكاء الاصطناعي، وتكنولوجيات أخرى من الثورة الصناعية الرابعة. وفي عام 2018، بدأت الإسكوا بتنفيذ أنشطة في هذا المجال: فعقدت اجتماعاً إقليمياً لفريق من الخبراء بشأن التكنولوجيات الرائدة، واختارت موضوع "التكنولوجيا من أجل التنمية المستدامة في المنطقة العربية" لدورتها الثلاثين، ونظّمت حلقة عمل بشأن التكنولوجيات الرائدة والنُظم التعليمية، ونشرت عدة تقارير عن التكنولوجيات الرقمية والابتكار من أجل التنمية. وهذا التقرير هو أول منشور تعدّه الإسكوا عن تكنولوجيات الثورة الصناعية الرابعة، ويتناول كيفية تفاعل الناس مع التكنولوجيا. وخلافاً للتقارير السابقة المنشورة في المنطقة، يركز هذا التقرير بشكل أساسي على تكنولوجيات الثورة الصناعية الرابعة بدلاً من الأدوات الرقمية التمكينية، ويدعو إلى اعتماد نُهُج قائمة على الحقوق في وضع إطار متين يتيح تطوير التكنولوجيات الرائدة واستخدامها على نحو مسؤول، ولا سيما تكنولوجيا الذكاء الاصطناعي، التي ينبغي أن تشكل جزءاً أساسياً من سياسات وممارسات الأعمال التجارية.

ويسلّط هذا التقرير الضوء على أهمية الثورة الصناعية الراهنة والتحديات الإنمائية الرئيسية في البلدان العربية. ويبيّن أن التطورات التكنولوجية المتسارعة أدت إلى آثار مزعزعة طالت جميع مجالات الحياة. ومع ذلك، يؤدي التقارب في التكنولوجيات إلى تحسينات لا تحصى، تظهر في آثارها الإجمالية. وقد نجحت التطبيقات المتعددة التخصصات في زيادة التحسينات وفي تحقيق إنجازات كان يُعتقد أنها مستحيلة.

ورغم انتشار التكنولوجيات الجديدة في مختلف المجالات، كثيراً ما تدفع حالات النزاع وعدم الاستقرار العديد من البلدان العربية إلى تغيير مسار خططها الإنمائية وأولوياتها العامة، فيما تؤدي الضغوط الناجمة عن النمو السكاني وتغيُّر المناخ إلى تدهور الظروف في المستوطنات الحضرية المكتظّة.

ويعرض هذا التقرير المساعي والمبادرات المتصلة بالثورة الصناعية الرابعة في البلدان العربية. ولا يمكن أن يكون هذا العرض شاملاً نظراً لطبيعة الاقتصاد الجديد المعروف بـ "اقتصاد العربة"(gig economy)،

لكنّه يعرض أبرز الأعمال ذات التأثير الظاهر والكبير التي تُنفَّذ على المستوى المحلي. وبالاستناد إلى الاتجاهات العالمية وإلى السياق الاقليمي والمعرفة المتوفرة، يتناول التقرير عشراً من تكنولوجيات الثورة الصناعية الرابعة في البلدان العربية. وتشير مستويات الأنشطة، والبحث، والتطوير، والتطبيقات المتعلقة بتلك التكنولوجيات إلى ما بلغته المنطقة من نضج وإلى استشرافها للمستقبل في عدة قطاعات واعدة. ويتيح العديد من التكنولوجيات مجالات محتملة للنمو في مجالي التطبيقات والتطوير. وقد حظيت برامج البحث والتطوير في المنطقة مؤخراً باهتمام سياسي قوي لجهة دعم الشركات الناشئة، ودعم الابتكار في إيجاد حلول تكنولوجية. وتنمو عدة مجالات تركيز وطنية، من دون تدخلات، بفعل التحديات المحلية وتحفيز مواهب الشباب واهتماماتهم.

ويبين هذا التقرير أبرز التهديدات المتزامنة الناجمة عن الارتفاع الموعود في إنتاجية الثورة الصناعية الرابعة. وفي هذا الإطار، يُقيِّم التأثير على التشغيل من زوايا متعددة باستخدام البيانات المتوفرة من المنطقة. وقطاع الصناعات التحويلية، وهو الأكثر تأثراً بتكنولوجيات الثورة الصناعية الرابعة في العالم، ضعيفٌ في البلدان العربية ويمثل في المتوسط نحو 10 في المائة من الناتج المحلي الإجمالي. لذا، قد لا تتأثر المنطقة على نحو سلبي في هذا المجال مثل البلدان الصناعية الأخرى. وتندر إجمالاً في المنطقة وظائف التجميع والتحويل القابلة للأتمتة في المجال الصناعي. ومعظم الوظائف المتوفرة في البلدان العربية هي وظائف في قطاع الخدمات. وتشمل كل وظيفة عدة أنشطة غير قابلة للأتمتة التامة. وعندما تتاح اليد العاملة المحلية الشابة والوفيرة بكلفة ميسورة، تزيد التكنولوجيات النموذجية للثورة الصناعية الرابعة من إنتاجية الإنسان بدلاً من أن تحل محلها. وتنتمي معظم النساء العاملات في المنطقة إلى فئة أصحاب المهارات العالية في قطاع الخدمات، ما يجعلهنّ أقل تأثراً من الرجال بالأتمتة الناجمة عن الثورة الصناعية الرابعة. ويؤدي توخي الفعالية في التخطيط وإعداد برامج التعليم والتدريب، إذا ما اقترن بسياسات تجارية واجتماعية محددة الأهداف، إلى تحويل الثورة الصناعية الرابعة إلى عامل محفّز للتشغيل في المنطقة، باستثناء عدد قليل من البلدان العربية حيث تساهم الزراعة بنسبة عالية من الأنشطة الاقتصادية (كما في السودان وموريتانيا).

والثورة الصناعية الرابعة بما لها من قدرة على دعم التنفيذ الفعال لخطة التنمية المستدامة لعام 2030 في البلدان العربية، تتيح فرصاً استثمارية مربحة في مجالات عدة، منها إعادة الإعمار، والتنبؤ بالكوارث والتعافي منها، وإدارة أزمة اللاجئين وحلها، وتمكين المرأة، وصنع السياسات، والاستهلاك المسؤول للموارد الطبيعية وإدارتها المتكاملة، وإدارة الأصول الثقافية واستكشافها، والتنمية الاقتصادية الشاملة، والتصنيع ذات القيمة المضافة.

ويتناول هذا التقرير الأدوار الرئيسية التي يمكن أن تؤديها الجهات المعنية المختلفة لضمان عدم إهمال المنطقة العربية في أعقاب الثورة الصناعية الرابعة، كما حصل خلال الثورات الثلاث السابقة. وهذا التقرير موجّه إلى عدة جهات معنية من حكومات وقطاع خاص ومجتمع مدني وأوساط أكاديمية.

Executive Summary

The present report reviews discussions on the Fourth Industrial Revolution (4IR) in the context of Arab countries. The Economic and Social Commission for Western Asia (ESCWA) supports Arab countries in that regard by providing relevant knowledge, convening regional stakeholders, and advising technical services in areas related to information and communication technology (ICT) policies, tracking and governance; and innovation strategies, policies and relevant institution building. In addition, for more than two decades, ESCWA has identified biotechnologies and prepared technology-focused meetings and reports to support critical industrialization for the future of manufacturing in Arab countries. However, following rapid technological developments since 2016, enabled by affordable speed of light communications, powerful computing and massive cloud information services and storage, the United Nations system adopted frontier and digital technologies, including big data, artificial intelligence and other 4IR technologies, as strong enablers for accelerating the implementation of the Sustainable Development Goals (SDGs). ESCWA initiated related activities in 2018: it organized a regional expert group meeting on frontier technologies, hosted the thirtieth ESCWA session on the theme “Technology for sustainable development”, organized a workshop on frontier technologies and educational systems, and published several reports on digital technologies and innovation for development. The present report is the first ESCWA publication on 4IR technologies, and discusses how people interact with technology. Unlike previous reports published in the region, it focuses primarily on 4IR technologies rather than digital enablers, and advocates adopting rights-based approaches to develop a robust framework for the responsible development and use of frontier technologies, namely artificial intelligence, which should form an essential part of business policy and practice.

The present report highlights the significance of the current industrial revolution, and of key development challenges in the Arab countries. It shows that the impact of accelerated technological developments has proven disruptive in all areas of life. However, the convergence of technologies is enabling accumulated improvements in their overall impact, and multidisciplinary applications have succeeded in augmenting improvements and mapping breakthroughs that were previously believed impossible.

In addition to the expansion of new technologies across the spectrum, many Arab countries are frequently derailed by conflicts and instability that alter their development plans and public priorities, while pressures exerted by population growth and climate change are exacerbating conditions in crowded urban settlements.

The present report provides a mapping illustration of 4IR-related endeavours and initiatives in Arab countries. The mapping cannot be comprehensive owing to the nature

of the new gig economy, but highlights impactful and visible work conducted locally. Based on global trends and regional context and knowledge, the report examines 10 4IR technologies in Arab countries. Levels of activities, research, development and applications related to those technologies indicate a degree of maturity and future foresight in the region for several promising sectors. Many technologies present or enable candidate growth areas in applications and development. Moreover, research and development programmes in the region have recently received strong political attention to support startups and innovation in technology solutions. Various national focus areas are being nurtured and are growing organically, driven by local challenges, youth talents and interests.

The present report highlights the eminent concurrent threats arising from the promised productivity benefits of 4IR. In that regard, the impact on employment is evaluated from several perspectives using available data from the region. The manufacturing industry, the sector most affected by 4IR technologies globally, is weak in Arab countries and represents on average around 10 per cent of GDP. Hence, the region might not be negatively affected like other industrialized countries. The typical automatable jobs in industrial assembly and processing are mostly absent from the region. Most existing jobs in Arab countries are in the service sectors and each job encompasses many activities, which are not fully automatable. Furthermore, typical 4IR technologies augment rather than replace human productivity when faced with young, abundant and affordable local labour. The majority of working women in the region are in the high-skills category of the service industry, and will be less affected than men by automation resulting from 4IR. Effective planning and development of education and training programmes coupled with targeted trade and social policies can turn 4IR into an employment driver, with the exception of a few Arab countries where agriculture represents a high percentage of economic activities (such as Mauritania and the Sudan).

The potential of 4IR in supporting the efficient implementation of the 2030 Agenda for Sustainable Development in Arab countries represents lucrative investment opportunities in reconstruction, disaster prediction and recovery, refugee crisis management and resolution, women's empowerment, policymaking, responsible consumption and integrated management of natural resources, cultural assets management and exploration, inclusive economic development, and added value industrialization, among others.

More importantly, the present report discusses the main roles that different stakeholders can play in making sure the Arab world is not left behind following the Fourth Industrial Revolution, as arguably was the case during the previous three revolutions. This report is targeted at multi-stakeholders, Governments, the private sector, civil society and academia.

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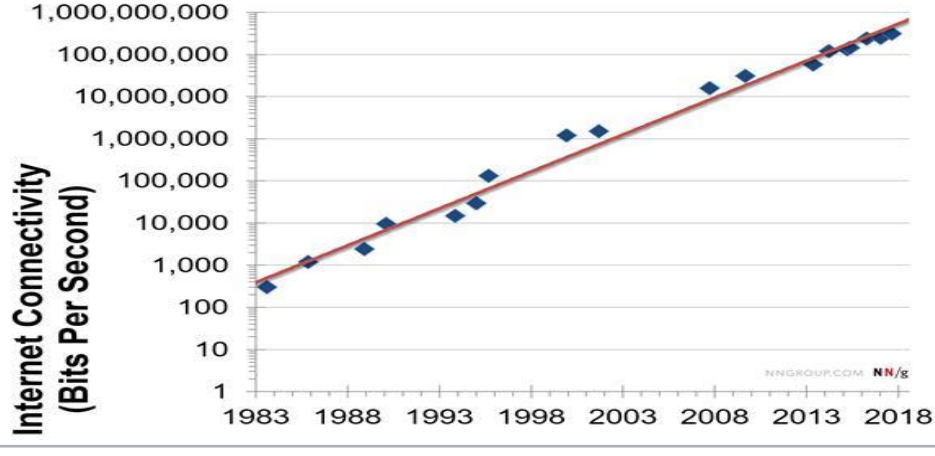
A. Introduction

Klaus Schwab, the founder and executive chairman of the World Economic Forum, has repeatedly highlighted progress and development resulting from the Fourth Industrial Revolution (4IR).[1] According to Schwab, what fundamentally distinguishes this revolution from the previous three (steam engine, electricity and digitization) is the rate, scope and impact of the convergence power of various disruptive technologies.

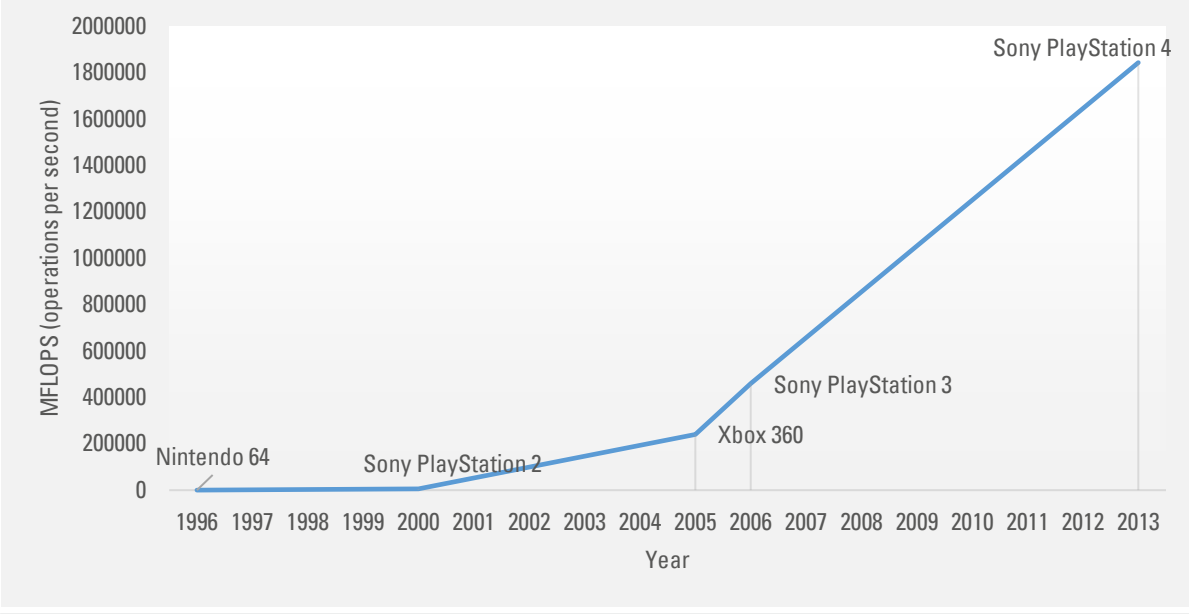
Rate of progress and performance measured by several technological advancement indicators (figure 1 and figure 2) has been demonstrated to be exponential (Moore's Law). Concurrently, the cost of these technologies has been corroded in the opposite direction implying the opposite of Moore's law, known as 'Eroom' law, thus yielding flooding trends in adoption rates: consider the growth in sales of industrial robots[2] (figure 3) and in that of mobile data traffic.[3] These indicators are relevant because of their economic impact. For example, according to Global System for Mobile Communications (GSMA), in 2017, mobile technologies and services generated 4.5 per cent of global GDP.[4] However, several such rates suffer from gender gaps, such as the 26 per cent reported gender gap in mobile Internet use in low- and middle-income countries (21 per cent in the Middle East and North Africa).[5]

Figure 1. Trend of bits per second for wireless devices



Source: Jakob Nielsen, Nielsen's Law of Internet Bandwidth, 1998.

Figure 2. Mega floating- point operations per second (MFLOPS) for popular gaming consoles



Source: Nick Routley, Visualizing the Trillion-Fold Increase in Computing Power, 2017.

Figure 3. Worldwide shipments of industrial robots

Source: International Federation of Robotics, Industrial Robot Sales Increase Worldwide By 31 Percent, 20 June 2018.

Another manifestation is the rate of advancement in just the last three decades, starting with the first commercially available atomic force microscope in 1989, the birth of the Internet in the early 1990s, the launch of Facebook in 2004, the release of the first iPhone in 2007, and the release of Tesla's Model 3 Sedan in 2017. An example of this progress can be seen in algorithms processed by super-fast computers, vast storage, and instant communications enabling artificial intelligence (AI) to beat humans at games: tic-tac-toe (1952), checkers (1994), chess (1997), Jeopardy (2011), some Atari games (2014), Go (2016), poker (2017), and Dota 2 (2017).[6]

In addition, the scope of 4IR and its associated frontier technologies[7] spans countless applications affecting all aspects of our lives, including health, education, manufacturing, agriculture, environment, water, energy, security, finance and transport. 4IR has led to the development of several brownfield and greenfield smart cities at the global and regional levels. Given the increasing number of smart cities, the International Telecommunication Union (ITU) undertook a detailed analysis of what defines a smart city,[8] and introduced a standardized definition for these cities by referring to them as 'smart sustainable cities'. ITU defined them as innovative cities that use ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that they meet the needs of present and future generations with respect to economic, social, environmental and cultural aspects. Such cities have six dimensions, namely: smart living, smart people, smart environment and sustainability, smart governance, smart mobility, and smart economy. Frontier technologies play a role in each of these dimensions, thereby affecting agricultural production, educational curriculums and methods, transportation systems, and treatment by precision medicine, among others.

We are living in an era of frontier technologies, which can be summed up with 6Ps: pervasive, perpetual, preventive, precise, predictive, and personalized. It is technology that is everywhere all the time, and predicts what you need before you need it and delivers custom-made service just for you. Therefore, frontier technologies have the potential to contribute to all Sustainable Development Goals (SDGs). Accordingly, the Secretary-General of the United Nations released the Strategy on New Technologies in which he states that "*Without a stepped up, smart and responsible use of technology, we will fail to reach the SDGs and we will miss opportunities to prevent conflict and sustain peace*".[9]

The 4IR will have a broad impact or "systems level" impact on our lives.[10] However, the quantified social, cultural, ethical, economic and legal implications remain unclear. Several questions are arising to which there is no short-term answers. What is a healthy dose of mobile phone use for kids? What are the ethical implications of AI making life and death decisions in medical cases? What should the restrictions be on autonomous weapons proliferation? What are the legal frameworks needed for autonomous vehicles? What is the impact of 4IR on employment, young people, gender equality, and the economic divide? These are all questions being debated at the global level. Consider the case of lethal autonomous weapons systems, which is currently being addressed by the United Nations Convention on Conventional Weapons.[11] How do we control the proliferation of such technologies? How do we monitor compliance

with conventions when the weapon is a software? Another example of the lag in systems to cope with progress is the national level legislation needed for unmanned aerial vehicles (drones), which is yet to mature in developed countries such as the United States of America, and was recently initiated in most developing countries years after the technology became mainstream.[12] For example, Egypt has just issued regulations on the use and commercialization of drones, and most other Arabic countries are enacting such legislation.[13] The use of drones has significant implications for security and privacy. This technology is expected to cause further disruption, particularly in the supply chain and transport domains.

The systems level disruption brought about by 4IR can be seen by comparing the three largest car companies in Detroit, United States, in 1990 with the three largest technology companies in Silicon Valley, United States, in 2014. The Detroit group had a market capitalization of $36 billion, annual revenues of $250 billion, and employed 1.2 million workers. The Silicon Valley counterpart had an explosive market capitalization of $1.09 trillion, annual revenues comparable to Detroit at $247 billion but with about a tenth of the workforce at 137,000.[14]

The disruptive features of 4IR are further amplified by the convergence of several technologies, such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, material science, energy, blockchain, and quantum computing. The convergence is manifested by progress in one technology enabling more progress in others. Their convergence is partly due to the maturity and scalability of ICT, which has enabled access to information on an unprecedented scale. This access has had a profound impact on education, research[15] and knowledge in all fields. This is promising considering that in 2018, the Internet penetration rate in Arab countries was 54.7 per cent compared with the world average of 51.2 per cent. However, some countries demonstrated impressive Internet penetration rates in 2017, such as Bahrain at 95.88 per cent, Kuwait at 98 per cent, Jordan at 66.79 per cent, Lebanon at 78.18 per cent, Qatar at 95.94 per cent, Saudi Arabia at 82.12 per cent, Oman at 80.19 per cent, and the United Arab Emirates at 94.82 per cent.[16]

Given the validity of the above questions and the disruptive nature of the aforementioned technologies, the Special Rapporteur on the promotion and protection of the right to freedom of opinion and expression submitted a report, in accordance with Human Rights Council resolution 34/18, which explored the implications of AI technologies for human rights in the information environment, focusing in particular on rights to freedom of opinion and expression, privacy and non-discrimination.[17]

B. Key persistent development challenges in Arab countries

Arab countries have faced chronic development challenges over the past few decades. The region has witnessed numerous wars that have had various direct and indirect effects on development. Moreover, various national limitations in resources such as water, energy, food, finances and talent, are crippling local economies, employment, education, human rights, and gender equality. Furthermore, an upsurge in population is stressing demand for jobs, resources and services. This is leading to the rapid growth of cities across the region, such as Cairo, Casablanca and Baghdad, thus

posing unprecedented challenges in planning, managing and governance. In addition, climate change is further deteriorating water and food security, while increasing the intensity and frequency of natural disasters. Considering all these factors, the Arab region is facing a future full of threats and instability, as already witnessed in many countries today.

The population of the Arab region was estimated at over 420 million in 2018, and is expected to reach around 440 million by 2020.[18] In addition, economic growth (GDP annual percentage) in the region slowed to 1.1 per cent in 2017 compared with 3 per cent in 2016, and a world average of 3.1 per cent in 2017.[19] For the past decade, youth unemployment has been roughly double the world average (26.1 per cent versus 13.4 per cent in 2016).[20] The gap is alarming for women: for the same period, the female unemployment rate in the region was close to double that of males (38.7 per cent versus 22.5 per cent in 2016). In addition, considering the total labour participation rate over the past decade, women are more than 3.5 times less likely to participate in the job market (74.1 per cent males versus 20.8 per cent females in 2016).[21] This is worrying given the great progress in educational attainment for women in the Arab region. For example, Arab countries' Gender Parity Index for primary education increased from 0.85 to 0.94 between 1997 and 2017.[22] The Middle East and North Africa region still ranks last globally in the Global Gender Gap Index (2017 and 2018), which integrates economic, educational, health and political empowerment indicators.[23] Gender gaps even exist in areas such as Internet usage, where ITU estimates that Arab countries have the highest gender gap in the world.[24] Clearly, these gaps differ between Arab countries and, in several cases, are not only across gender but also across socioeconomic classes within the same country.

In 2016, the Networked Readiness Index did not include any Arab countries in the top 25. The highest ranked Arab countries were the United Arab Emirates (26th), Qatar (27th), Bahrain (28th) and Saudi Arabia (33rd), with the remaining Arab countries slipping below rank 50.[25] This Index provides an indicator of a country's ability to benefit from the digital revolution and its preparedness to benefit from the Fourth Industrial Revolution. Another technology index is the ICT Development Index 2017, where no Arab country reached the top 25. The highest ranked Arab countries were Bahrain (31st), Qatar (39th) and the United Arab Emirates (40th).[26]

The situation of natural resources also does not bode well for Arab countries,[27] considering that the average yearly national renewable water resources per capita has been below the poverty line level of 1,000 cubic meters for several years. Twelve Arab countries are under the 500 cubic meters a year threshold set by the World Health Organization for severe scarcity; it is estimated that by 2030, climate change will reduce these resources by another 20 per cent.[28] These numbers along with increased drought recurrence is expected to cause an alarming shortage of water for domestic and agricultural use, and directly impact the environment as seawater intrusion increases.

2. Mapping of 4IR technologies in Arab Countries

2. Mapping of 4IR Technologies in Arab Countries

Frontier technologies in the Arab region are applied in many countries and various areas. The region is experiencing a shift from technology consumption to technological localization and innovation. Several factors have contributed to this transformation, especially a change in mindset, a local culture of rewarding entrepreneurship, diminishing opportunities of educated young people in government employment, and fewer entry barriers to many enabling technologies.[29] This last critical factor is founded on the nature of the technology itself. In this regard, two aspects can be highlighted: the connectivity providing unprecedented free access to enormous information, and the softwarization of development in computing. Therefore, there is levelling in the field of technology development across boundaries and economic classifications. Accessibility to affordable venues for development, such as the cloud, has reduced the level of capital investment in facilities needed to be competitive. Box 1 gives a brief analysis on sample Arab initiatives, which are having an impact on the Fourth Industrial Revolution.

To develop a map of 4IR technologies in the Arab region, the present report focuses on the most potentially impactful technologies with multiplier effects. They are candidate technologies that can potentially be widely adopted today or in the near future. This mapping is meant to go beyond just digital ICT solutions, unless these solutions are employing 4IR technologies. The present report therefore focuses on technologies with a relatively low barrier to entry, both in terms of adoption and development. These technologies include artificial intelligence, 3-D printing, augmented and virtual reality, robotics, the Internet of Things, autonomous vehicles, nanotechnology, biotechnology, blockchain, and big data. Keeping in mind that the evaluation is only exploratory, the suggested assessment criteria is based on the following:

(a) Level and scale of current local activities;
(b) Holistic degree of the local production ecosystem;
(c) Readiness of enabling policies and capacities;
(d) Relevant local research and development activities.

The present report does not provide a comprehensive coverage of activities, but rather a specimen of the most prominent and visible 4IR cases in Arab countries. The three levels characterizing the above criteria are either: limited (not enough interest is exhibited in the field or in related policies); moderate (promising related activities are possible with potential future growth); significant (relevant stakeholders are active, and evidence is demonstrated with growth potential).

Box 1. Scope of 4IR development in Arab region

In 2017, the Government of the United Arab Emirates launched the One Million Arab Coders Initiative.[a] This prompted the World Economic Forum and the International Finance Corporation to jointly select the 100 Arab world startups (the final list included 110 startups) impacting the Fourth Industrial Revolution.[b] An analysis of the 110 selected startups, showed that the number per country varied between 1 and 27. This is an indicator of the disparity in progress between different Arab countries. Among the most common domains of applications were retail, finance, gaming, education, energy, telecommunication, health and medical, Arabization, media, speech recognition, agriculture, and real estate. The absolute majority of startups (about 96 per cent) fell in the realm of digital technologies with software being the dominant theme, and few included significant hardware components. Artificial intelligence was the dominant theme related to 4IR technologies. Specifically, nine startups were developing or deploying AI, and three ventures had innovated based on augmented and virtual reality. One startup in each of the following areas made the subject list: nanotech, telehealth, drones and bitcoin.

Source:

[a] http://www.arabcoders.ae/en/.

[b] https://widgets.weforum.org/arabstartups/.

A. Artificial intelligence

Since progress in computing and AI is possible using existing software platforms, there is significant potential for AI not only to be widely adopted in applications in the region but also to be developed regionally. Several Governments have taken note of this, with the United Arab Emirates appointing the world's first artificial intelligence minister[30] and developing the Emirati Strategy for Artificial Intelligence,[31] and the Dubai police employing AI in the Oyoon project.[32] Moreover, in collaboration with Hamdan Bin Mohammed Smart University, the first artificial intelligence faculty in Egypt was inaugurated at Kafr El-Sheikh University, awaiting the new class of 2019/2020 to produce skilled labour for the smart systems sector.[33]The Dubai Electricity and Water Authority is using an AI chatbot to provide customer services, and Saudi Arabia has revealed its first robot using AI, Sophia.[34] Tunisia has begun efforts to establish a national AI strategy.[35] Regional businesses are also embracing AI, such as Aramex Bot which provides customer services via Facebook messenger;[36] and INFINITI which launched Idris, a virtual assistant.[37] In Morocco, there is sizable deployment of AI in the services sector.[38] Box 2 highlights several startups in the Arab region that are making use of AI technology.

International Data Corporation estimated that the AI market in the Middle East and Africa region will reach $100 million by 2021.[39] The mapping shows that e-commerce, media and education seem to be the top three application domains for AI in the region. This progress has encouraged the establishment of incubators, such as the NU TechSpace in Egypt, focused on supporting primarily AI and blockchain startups.[40] The level and scale of current activities, startups, deployments and competition seem to be significant in the region. The ecosystem, which is based on software companies, is strong. In addition, there are no special policies or regulations needed for AI use in most domains, other than the medical sector. This leads the present report to conclude that AI adoption and development are expected to be high in the Arab region.

Box 2. Examples of startups using AI in the Arab region

Several startups focusing on the use of AI have emerged in the Arab region,[a] including WideBot (chatbot, Egypt),[b] Mujeeb (chatbot, Syrian Arab Republic),[c] Seez (car sale, Lebanon),[d] Noon Edu (education, Saudi Arabia),[e] Narrativa (journalism, United Arab Emirates),[f] Comae Technologies (cyber security, United Arab Emirates),[g] Acacus Technologies (transport, Jordan),[h] Crowd Analyzer (media, United Arab Emirates),[i] Cognitev (media, United Arab Emirates),[j] and brndstr (e-commerce, United Arab Emirates).[k] Notable activities are being undertaken in Lebanon: Cherpa (education), Giftlivery (e-commerce), Neotic (fintech), Augmental (education), Lexium (legal), Tapklik (media), and NAR (inspection). It is worth mentioning Lableb from Abu Dhabi, the Arabic search engine using AI for search results and Arabic natural language processing.[l]

Source:

[a] https://en.annahar.com/article/784244-prominent-artificial-intelligence-startups-in-mena.
[b] https://widebot.net/.
[c] https://mujeeb.ai/.
[d] https://seez.co/.
[e] https://www.noonacademy.com/.
[f] https://www.narrativa.com/.
[g] https://www.comae.com/.
[h] http://www.acacusgroup.com/.
[i] https://crowdanalyzer.com/.
[j] https://www.cognitev.com/.
[k] https://brndstr.com/#home.
[l] https://lableb.com/.

B. Augmented reality and virtual reality

There are a variety of startups in the Arab region in the virtual reality (VR) domain, as the benefits of VR and augmented reality (AR) are taking the spotlight in current technology development.

According to International Data Corporation, the AR and VR market in the region will reach $6 billion by 2020.[41] Businesses are embracing the technology, with Etihad Airways, Jumeirah Group, Dubai Electricity and Water Authority, and Bareburger restaurant adopting VR technology to improve their customer experiences.[42] AR adoption is expected mainly in m-commerce and user experience,[43] in the domains of tourism, transport, health care and education.[44]

Box 3. Most impactful startups in the VR domain in the Arab region

Gigaworks (United Arab Emirates, media and entertainment), Pixelbug (United Arab Emirates, entertainment),[a] Takeleap (United Arab Emirates, real estate),[b] Sfearia (Lebanon, medical),[c] 5dVR (Egypt, entertainment and media),[d] BSocial (Egypt, media),[e] VRteek (Egypt, entertainment),[f] and EpicVR (Egypt, entertainment).[g] Other interesting startups applying AR technology include Proximie (Lebanon, medical),[h] PearlQuest (United Arab Emirates, media), EventAgratE (United Arab Emirates, media),[i] VRapeutic (Egypt, medical),[j] LIVIT (Egypt, education),[k] VR EGYPT (Egypt, education),[l] Incept (Tunisia, media),[m] Visual Experience (Saudi Arabia, media),[n] and Innotech (Oman, education/gaming).[o]

Source: CairoScene, 8 VR startups in the MENA region that will reshape the future, 29 October 2017.

[a] https://pixelbug.com/.
[b] http://takeleap.com/.
[c] https://www.f6s.com/sfearia.
[d] http://www.5d-vr.com/.
[e] https://bsocial-eg.com/.
[f] https://vrteek.com/.
[g] http://epicvr.net/.
[h] https://www.proximie.com/.
[i] http://eventagrate.com/.
[j] http://myvrapeutic.com.
[k] http://livitstudios.com/.
[l] http://avregypt.com/.
[m] http://www.incept.tn/.
[n] https://visual-ex.com/.
[o] http://innotech.om/.

The level and scale of current activities, startups and deployments appear significant, and market size estimates are high. The ecosystem, which is based on software companies, is strong. In addition, there are no special policies or regulations needed for using AR and VR in most sectors. The conclusion is that adoption and development are expected to be high.

C. Robotics and automation

Several initiatives around robotics, automation, instrumentation, vision and mechatronics are active in the region. These include a significant number of national and regional competitions. Two notable regional competitions are Vex Robotics[45] and First Lego League[46] organized by the Arab Robotics Association,[47] which produced competitive teams such as the Lebanese team “Fast and Curious” that went on to win the world championship in the United States in 2014, and the Jordanian team “Robo Ibdaa” that recently won the mechanical design award in the United States competition.[48] An international competition from the region that has one of the largest awards in robotics competitions is the AI and Robotics Award for Good of the United Arab Emirates.[49] A similar international competition from the United Arab Emirates targets startups is the Drone Innovation Start-up Contest 2018, launched by Krypto Labs.[50] Another bold initiative is outlined by the Space Agency of the United Arab Emirates, which is planning a robotic mission using Hope, the country’s Mars probe. Moreover, on 29 October 2018, the Mohammed bin Rashid Space Centre in Dubai launched KhalifaSat, the first satellite developed independently at the centre.[51] Egypt also has plans for launching satellites manufactured mostly locally.[52]

Egypt has a good number of robotics and automation companies, including EMAR (robotics),[53] QEYE (vision),[54] Creative Bits (robotics),[55] and MENA Robotics (robotics education).[56] In Tunisia, Enova Robotics is one of the few companies in the region with its own robotic brand.[57] Lebanon has also launched innovative products such as Instabeat, the first waterproof heads-up swimming wearable;[58] Roadie, the first automatic guitar tuner;[59] and Slighter, the award-winning lighter that helps smokers reduce or quit smoking.[60] WakeCap (United Arab Emirates)[61] is conducting interesting work in wearables for construction, and Yatooq (Saudi Arabia)[62] has launched automated Arabic coffee making. Advanced work using vision technology and drones is being done by FalconViz (Saudi Arabia, drones/vision).[63] Other Saudi startups include Nomadd that has developed a robotic cleaner for solar panels in desert-like conditions,[64] and Insyab that has developed wireless technology for collaborative robotics applications.[65]

Significant focus is being placed on educational and inspirational aspects of robotics, as with Junkbot Robotics (Dubai),[66] the Little Engineer (Lebanon),[67] and Edutech (United Arab Emirates),[68] in addition to the establishment of several makerspaces in the region such as Fab Lab Egypt (Egypt),[69] Cairo Hackerspace (Egypt),[70] Fikra Space (Iraq),[71] Lamba Lab (Lebanon),[72] Originbase (United Arab Emirates),[73] Prototyping Center (Oman),[74] Fablab Casablanca (Morocco),[75] and TekSpacy the ‘women only’ makerspace (Saudi Arabia).[76]

The level and scale of current activities in the region appear significant. The mapping shows considerable effort and progress in competitions and hackathons, which are excellent mechanisms to spark student interest at all levels. In addition, there is a reasonable

level of education activities and access to makerspaces. However, the manufacturing part of the ecosystem, which is based on hardware manufacturers, is relatively weak. Some regulations are required for robotics and instrumentation in the medical field, which are lacking in the region. The conclusion is that adoption and development are expected to be at a moderate level.

D. Internet of Things

Dubai prepared the Smart Dubai Internet of Things (IoT) Strategy to develop the most advanced IoT ecosystem globally.[77] Some startups in the region are developing relevant technology, including Scriptr (software platform, Lebanon),[78] Verboze (hotel automation, Lebanon),[79] Sadeem (wireless sensing, Saudi Arabia),[80] and Si-Vision (wireless protocols, Egypt).[81] Deloitte estimated an IoT installed base in the Middle East of 70 million devices by mid-2016, with 25 million devices shipped to the region in 2015.[82] International Data Corporation estimates MENA spending on IoT reaching $12.62 billion by 2021.[83] The main markets will include Saudi Arabia and the United Arab Emirates, with the main sectors being transport, fleet management and monitoring.[84] According to A.T. Kearney, the IoT solution market in Gulf Cooperation Council (GCC) countries is expected to reach $11 billion within the next decade,[85] with the largest sectors being utilities, public administration, retail and wholesale, housing and construction, and transport and logistics. This led the chipmaker Intel to open the IoT Ignition Lab in Dubai Silicon Oasis. The lab focuses on smart cities, smart homes and smart transportation.[86] In addition, this encouraged the establishment of specialized accelerators focused on IoT and robotics, such as Brinc in Bahrain,[87] Dubai Smart City Accelerator and Dubai Future Accelerators[88] with focus on IoT, AI, blockchain and other aspects of smart cities. Another notable initiative is the Qatar Mobility Innovations Centre (QMIC), an innovation centre focused on smart mobility systems and services. QMIC is becoming a leader in IoT solutions for intelligent transport, logistics and telematics, road safety and environment.[89] At the infrastructure level, several operators in Tunisia are already obtaining licenses to provide IoT services.[90] All these activities align with the Saudi Arabian ambitious initiative NEOM, a smart city of the future embracing most 4IR technologies, to be established in the region of Tabuk.[91]

The level and scale of current activities, startups and deployments in the region appear significant, and market size estimates are high. However, the manufacturing part of the ecosystem, which is based on hardware manufacturers, is relatively weak but the part related to networking and communication is strong. No special regulation requirements are needed. The conclusion is that adoption is expected at a high level, but development is expected at a moderate level.

E. Autonomous vehicles

Regional development or production in this area is expected to be minimal, but adoption does exist in some limited markets like Qatar, Saudi Arabia and United Arab Emirates. The Emirati Roads and Transport Authority has already adopted protocols for testing autonomous vehicles,[92] and the Dubai police have plans to use autonomous vehicles by 2020.[93] Oman has assessed preparedness and regulations needed to adopt autonomous vehicles.[94] This issue is

considered of such high importance that the King Abdullah Economic City in Saudi Arabia revised its masterplan to take into consideration driverless cars.[95] In addition, Qatar is moving forward with plans for commercial use of driverless vehicles.[96] Derq is an Emirati company looking at using AI to reduce road accidents by predicting the possibility of an accident.[97] In some cases, Arab countries can offer a unique environment for testing, as is the case with Morocco. Mars-like terrain in Morocco is being used to test the automated navigation systems of space robots.[98]

The level and scale of current activities, startups and deployments in the region is limited. In addition, the manufacturing part of the ecosystem, which is based on hardware manufacturers, is relatively weak. This area is highly demanding in terms of regulations and policies, which are lacking in most Arab countries. The conclusion is that adoption and development are expected to be at a low level.

F. Nanotechnology and advanced material

In the Arab region, most work in this area is limited to research in universities and centres. In Saudi Arabia, King Abdulaziz City for Science and Technology established the Joint Centre of Excellence in Integrated Nanosystems in collaboration with Northwestern University;[99] King Saud University established the King Abdullah Institute for Nanotechnology;[100] King Abdullah University of Science and Technology established several nanotechnology laboratories;[101] King Fahd University of Petroleum and Minerals established the Centre for Research Excellence in Nanotechnology;[102] and King Abdulaziz University established the Centre of Nanotechnology.[103] This resulted in Saudi Arabia ranking eleventh worldwide in the 2017 list published by United States Patent and Trademark Office, with 92 patents. Moreover, King Abdulaziz University ranked twenty-seventh worldwide and King Saud University ranked forty-fifth worldwide in ISI indexed nano-articles, with 897 and 707 articles, respectively.[104] The Egypt Nanotechnology Centre was established by the Egyptian Government in collaboration with IBM,[105] and the American University of Cairo established the Yousef Jameel Science and Technology Research Centre.[106] Another nanotech focused institute in Egypt is the Centre for Nanoelectronics and Devices.[107] Nanotechnology in Qatar is primarily developed by the Qatar Energy and Environmental Institute,[108] under the Hamad Bin Khalifa University and the Centre of Advanced Materials at Qatar University.[109]

In the United Arab Emirates, Khalifa University's Masdar Institute includes several research centres focused on nanotechnology and its applications,[110] and Ras Al Khaimah Centre for Advanced Materials is a leading institute in material and nanotechnology.[111] In Jordan, the University of Jordan established the Hamdi Mango Centre for Scientific Research,[112] and the Higher Council for Science and Technology established the National Centre for Research and Development.[113] In Kuwait, the Kuwait Institute for Scientific Research conducts research in several areas related to nanotechnology.[114] In Morocco, the Moroccan Foundation for Advanced Science, Innovation and Research Institute is also conducting research in several fields of nanotechnology.[115]

Nanotechnology research in the region is focused on applications in the petroleum, energy, water and health sectors.
A comprehensive coverage of nanotechnology

activities in the Arab region was conducted in 2013.[116] A recent success story was the Lebanese inventor Fouad Maksoud, graduate of the American University of Beirut, who won the Arab innovation programme Stars of Science with an electrospinning industrial machine for nano-fibre fabric shielding called Nanoskin.[117] In addition, Saudi Aramco scientists developed a new inspection method based on nanostructure response, which can be applied to aircraft materials and wind turbine blades.[118] Nanotechnology has numerous applications in the field of material, medicine, energy, agriculture, instrumentation, water desalination and petrochemicals.[119] One startup in Saudi Arabia, QD Solar, is applying colloidal quantum dot technology to improve productivity in photovoltaic cells.[120] Other Saudi startups include Nanosferix, which is developing light reinforced advanced material,[121] and Quantum Solutions which focuses on developing quantum dots and advanced material.[122]

The level and scale of current activities, startups and deployment in the region is limited. Research activities are strong, but the manufacturing part of the ecosystem, which is based on specialized hardware manufacturers, is weak. No special regulations are required in this area, except for medical applications. The conclusion is that adoption and development are expected to be at a moderate level.

G. Biotechnology

One of the most promising areas impacting health is biotechnology. A big success story in the region is Hikma from Jordan, with branches in almost all Arab countries.[123] Hikma operates 29 manufacturing facilities in 11 countries. Two other Jordanian pharmaceutical manufacturers are MSpharma[124] and Dar Al Dawa.[125] Algorithm is another successful pharmaceutical company from Lebanon.[126] Interestingly, most winners of the International Rising Talents 2018 of the L'Oréal-UNESCO for Women in Science in the region are scientists in the field of biotechnology and materials.[127] Another award-winning female scientist invented an efficient process to convert plastics into biofuel. Regarding startups, the Saudi KAUST Innovation Fund has supported PepPrint in providing 3D/4D bioprinting,[128] and Noor DX in providing genotyping services.[129] In addition, KAUST recently celebrated the launch of the Saudi Vaccine and Biomanufacturing Centre, a unique research and industrial centre in the Arab region.[130]

Several research centres and incubators have been established in the region specializing in biotechnology, including Institut Pasteur de Tunis (Tunisia),[131] the Centre of Biotechnology of SFAX (Tunisia),[132] Institut Pasteur d'Algerie (Algeria),[133] Institut Pasteur du Maroc (Morocco),[134] and the Azm Centre for Research in Biotechnology and its Applications (Lebanon).[135] The Badir Biotechnology Incubator in Saudi Arabia is another notable initiative supporting biotechnology innovation in several sectors, such as health, medicine, pharmacy, the environment and agriculture.[136]

The level and scale of current activities, startups and production in the region is limited. In addition, the manufacturing part of the ecosystem, which is based on either pharmaceutical or research centres, is moderate. This is a relatively highly regulated sector. Given the population of the region, the market size is significant. The conclusion is that adoption is expected to be at a high level and development is expected to be at a moderate level.

H. 3-D printing

This is one of the main technologies promising to bring manufacturing closer to home. One example is the deal between Siemens AG, Strata Manufacturing PJSC and Etihad Airways to design and manufacture 3D-printed aviation parts in the United Arab Emirates.[137] Moreover, the Dubai 3D Printing Strategy aims to reduce costs and improve efficiencies in several sectors in preparation for Expo 2020. The strategy aims to ensure that 25 per cent of buildings are based on 3D printing technology by 2030, and low-cost 3D printed artificial limbs by 2025.[138] Accordingly, Dubai inaugurated the first 3D printed office building in 2016, which was constructed in 17 days, and the first 3D printed autonomous car.[139] Jordan also has initiatives at the national level led by the Crown Prince Foundation to establish FabLabs, which are workshops for facilitating digital fabrication.[140] In Lebanon, Buildink is developing a concrete 3D printer using a proprietary concrete mixture focused on home building.[141] In Egypt, 3D printers are being locally manufactured by Robota, which is also specialized in dental equipment manufacturing.[142] In Morocco, Thales has established an industrial competence centre focusing on metal 3D printing.[143]

Regionally, the 3D printing market is expected to increase from $0.47 billion in 2015 to $1.3 billion by 2019.[144] There is interest in sectors such as oil and gas, owing to challenges faced in getting replacement parts in remote and secluded sites.[145] Other sectors such as public transport are making use of the technology, as is the case with Dubai's Roads and Transport Authority which uses 3D printed spare parts to service ticket machines.[146] Medativ, also based in Dubai, is a startup specialized in 3D anatomical models for better medical intervention planning.[147]

The level and scale of current activities, startups and deployments in the region is moderate, with more activities on the deployment side. The market is expected to be sizable. However, the manufacturing part of the ecosystem, which is based on specialized hardware manufacturers, is weak. No special regulations are required in this area, except for medical applications. The conclusion is that adoption is expected to be at a high level, while development is expected to be at a low level.

I. Blockchain

The United Arab Emirates is leading the regional adoption of blockchain technology. For example, Smart Dubai and IBM are working on the Dubai Blockchain Platform, which is a service platform endorsed by the Government.[148] The potential is considered so significant that the region is holding events solely focused on applying blockchain, such as Blockchain Applied and the Blockchain Summit both held in Dubai,[149] and the Blockchain Developer bootcamp held in Beirut.[150] This has encouraged the establishment of startups providing market access to cryptocurrencies, such as bitcoin, targeting the Arab region as with BitOasis.[151] This has also encouraged the establishment of blockchain focused incubators, such as the one founded at the Nile University in Egypt.[152] The Central Bank of Lebanon announced that they will be implementing blockchain technology, and that they are extensively researching the implementation of digital currency.[153] Moreover, the Central Bank of the United Arab Emirates and the Saudi Arabian Monetary Authority will issue a cryptocurrency that is accepted in transactions between the two countries.[154]

A unique use of blockchain and its first use for humanitarian aid comes from the World Food

Programme: Building Blocks manages the cash-for-food aid programme for over 100,000 Syrian refugees in Jordan.[155] The Bahrain Government is also encouraging local companies to adopt the technology, and the Bahrain Institute of Banking and Finance has launched the Blockchain Academy.[156] In Egypt, Codeaku is a startup establishing the first blockchain school in the country.[157] An interesting initiative is the world's first utility-scale blockchain infrastructure in Morocco:[158] the computing firm Soluna is establishing a wind powered 9000MW power plant to use in powering blockchain computation in an eco-friendly way.[159] Furthermore, Tunisia was the first nation to allow for its currency to be exchanged via cryptocurrency technology.[160]

The level and scale of current activities, startups and deployments in the region is moderate, with more activities on the deployment side. The ecosystem, which is based on specialized software companies, is strong. Regulations are required in this domain, particularly the financial sector. The conclusion is that adoption is expected to be at a moderate level, while development is expected to be at a low level.

J. Big data

Big data involves data analysis, visualization and storage/computation infrastructure. The region is seeing an increased growth in infrastructure, with more data centres being established.[161] The International Data Corporation expects the market size in this area to reach $3.2 billion by 2020.[162] The largest investors in the region have been Governments (20.4 per cent), the financial sector (19.2 per cent) and telecommunication companies (13.3 per cent).[163] Another estimate puts the market at $12.38 billion by 2020.[164] This technology is a key asset for the region, given that some Arab Governments are making strides towards e-government. In the E-Government Development Index 2018, the United Arab Emirates ranked twenty-first worldwide, Bahrain ranked twenty-sixth, and Kuwait ranked forty-first.[165] One accelerator focused on harnessing the power of the cloud is the C5 Accelerator in Bahrain, helping regional startups scale through cloud computing.[166]
On the analytics side, Geomatic (Morocco), with a long experience in GIS technologies, is now adding value through big data analysis and visualization.[167] Several countries in the region are home to datacentres, such as Jordan and Egypt.[168]

The level and scale of current activities, startups and deployments in the region is moderate, with more activities on the deployment side. The market is expected to be significant. The ecosystem, which is based on software and ICT services, is strong. Special regulations are required in this area, especially for medical applications. The conclusion is that adoption is expected to be at a high level, while development is expected to be at a moderate level. Table 1 shows the present capacity in research and development in most of the assessed technologies. Furthermore, it shows strong ecosystems in the areas based on ICT infrastructure. Policies and regulations need immediate attention in most selected technology areas. Table 1 suggests existing opportunities in AI, IoT, nanotechnology and biotechnology, where there are significant research programmes and capacity.

Table 1. Summary of evaluated 4IR technologies in Arab countries

4IR Technology	ACTIVITIES	ECOSYSTEM	POLICIES	R&D
Artificial intelligence	Significant	Significant	Moderate	Significant
Augmented/virtual reality	Moderate	Significant	Moderate	Moderate
Robotics and automation	Moderate	Limited	Limited	Moderate
Internet of Things	Significant	Limited	Moderate	Significant
Autonomous vehicles	Limited	Limited	Limited	Limited
Nanotechnology	Moderate	Limited	Moderate	Significant
Biotechnology	Moderate	Limited	Limited	Significant
3D printing	Moderate	Limited	Moderate	Limited
Blockchain	Moderate	Significant	Limited	Limited
Big data	Limited	Significant	Limited	Moderate

Source: Prepared by ESCWA.

All this progress in the region in various 4IR areas would not be possible or sustainable without a nurturing environment and strong infrastructure. During the past few years, there has been considerable progress in establishing productive ecosystems within Arabic countries. Although most initiatives are at the national level, it is a good initial start. These initiatives can be grouped under incubators and accelerators, technology parks, venture capital funds, and competitions. ESCWA estimates the existence of about 100 incubators and accelerators, 50 technology parks and 80 venture capital funds in the Arab region.[169] Competitions like the Arab Startup Competition,[170] TechCrunch Startup Battlefield MENA,[171] Hult Prize,[172] Hajj Hackathon[173] and Global Entrepreneurship Week,[174] and television series like Stars of Science,[175] have become a regular fixture of the Arab region entrepreneurship scene. Specialized regional platforms, such as Wamda[176] and MIT Enterprise Forum Pan Arab[177] which focus on enabling the entrepreneurship ecosystem in the Arab region, are becoming more common and effective.

Although not all these organizations and activities are focused on 4IR technologies, it still provides an indicator of the change that the region is experiencing in the domain of technology development and commercialization, with still a long way to go to compete with international powerhouses like China and the United States. In the Forbes Top 100 Startups in The Middle East, only seven are developing or adopting 4IR technologies, with the rest focusing on ICT ventures (apps and websites).[178]

The 4IR innovation ecosystem needs strong local research and development feeds. Many Arab countries are investing more in research and development: Egypt increased funding from 0.27 per cent of GDP in 2007 to 0.72 per cent in 2015, and Kuwait increased funding from 0.1 per

cent of GDP to 0.3 per cent.[179] Most GCC countries have established national funds to support innovation and entrepreneurship beyond research. Several Arab countries, including Bahrain, Saudi Arabia, Qatar and the United Arab Emirates, have recognized the importance of linking with the global ecosystem and have therefore established initiatives to link local startups.[180] Many cities are actively working to become regional hubs for entrepreneurship, including Abu Dhabi, Doha, Dubai, Jeddah, Manama, Muscat, Amman, Beirut, Cairo, Casablanca and Tunis.[181] These efforts have already been recognized. For example, Lebanon ranked fourth worldwide in Total Early Stage Entrepreneurial Activity, according to the Global Entrepreneurship Monitor 2017/2018 Global Report.[182] In the same report, Saudi Arabia ranked first worldwide in the Entrepreneurial Spirit Index, and the United Arab Emirates ranked first worldwide in the High Status of Entrepreneurs. Several reasons justify this high ranking in GCC countries, especially local laws governing the establishment of business and related national ownership requirements.

3. Employment and 4IR Regional Facts

3. Employment and 4IR Regional Facts

Historically technology has contributed to productivity growth since the First Industrial Revolution, and fear of 'technological unemployment' has emerged alongside every technological advancement in history, according to the International Monetary Fund.[183] However, such advances have led to improvements in living standards and per-capita GDP growth.[184] It is true that technology has displaced jobs in some sectors, but it has also increased real income thus yielding increased demand for goods in other sectors, which ultimately contributed to creating new jobs.[185] Although, there is no evidence of the long-term negative impact of technological advances on the job market, there is still no broad agreement on whether 4IR will result in a net gain or net loss in jobs globally. The challenge of assessing the impact of a technological revolution on employment in general is that it is coupled to rate of adoption, type, and domain of application of technological advancement. This makes it challenging to propose predictions regarding the types of jobs that will be replaced or created, and when this will occur.

For example, the first automobile was attributed to Nicolas-Joseph Cugnot in 1769; however, the first mass-production of cars was not realized until the days of Ford's Model T in 1913, over 140 years later.[186] This shows that employment is not only about technological advancements, but also depends on several market forces, including affordable mass production, supply chain and infrastructure. Therefore, predicting when a certain job category or sector will be impacted is challenging, and the foreseen influence will not occur overnight despite accelerated development which has considerably reduced the technology adoption lag.[187] Therefore, there is an opportunity to channel all available capacity in the productive value chain if planning and preparation are carried out adequately and in a timely manner.

Studies related to the impact of 4IR on employment are numerous and have applied different methodologies.[188] Some methods have relied on an analysis of skills and competencies needed for different jobs versus the technological capabilities available today, so as to evaluate the automation potential of activities and occupations.[189] Such a detailed analysis allows for the assessment of the proportional automation potential of a certain activity in an occupation. Another approach is to survey views and outlooks of human resource leaders in large organizations regarding several aspects of the future of jobs.[190] The academic literature includes several studies that attempt to develop models to predict the susceptibility of a job to automation. One such approach employs probabilistic classification techniques; ironically, these tools are similar to the technologies expected to contribute to job automation.[191]

A. Skills of the future

Most studies agree that the jobs of the future will require medium to high-level skills.[192] These categories are related to the level of education required for the job:

(a) Low skill: lower secondary or primary education;
(b) Medium skill: post or upper secondary education;
(c) High skill: first or second stage tertiary education.[193]

One regional study estimates that the potential for automation to replace activities is 55 per cent for jobs held by high school graduates, and 50 per cent for workers without high school certificates. This potential replacement drops to 22 per cent for jobs held by graduates with bachelor degrees or higher.[194] New jobs require skills in perception and manipulation, creative intelligence, and social intelligence.[195] In other words, these are jobs with the least risk of being automated. Perception and manipulation (jobs requiring high levels of sensory analysis and manual dexterity) are expected to remain a challenge for automation. A distinction is made between perception and manipulation in structured versus unstructured environments (factories versus construction sites, warehouses versus homes). In addition to this distinction, there are differences between system and model level changes. For example, the construction field is difficult to automate; however, technologies like 3D printing on site or the use of prefabricated structures are fundamentally changing the sector and will have a significant impact on the type of skills needed within the industry and on related jobs. These fundamental system changes cause a fundamental change in the type of skills needed within a certain industry. Another challenge to automation is creative intelligence tasks, which require the ability to come up with ideas that are novel and/or valuable.[196] Some of these abilities are being demonstrated by AI in the art domain (painting,[197] music composition);[198] however, cultural differences and creative values still pose a challenge to automation. The third set of tasks protected from automation are those related to **social intelligence (**negotiation, persuasion, care and mentoring).[199] Although progress has been made in affective computing, social robotics and human machine interaction, this field is still in its infancy.[200] The jobs of the future will require social and emotional intelligence, logical reasoning, and will be highly interdisciplinary.[201]

Another analysis of the activities involved in occupations from the *least* susceptible to the *most* susceptible to automation includes managing others, applying expertise, stakeholder interactions, unpredictable physical work, data collection, data processing, and predictable physical work.[202] A recent study by McKinsey Global Institute highlighted the three main skill sets needed by the markets of 2030.[203] These included higher cognitive skills, such as advanced literacy and writing, quantitative and statistical skills, critical thinking and complex information processing. These are applied by doctors, accountants, research analysts, writers and editors. The second skill set is social and emotional, including soft skills such as communication and negotiation, empathy, managing others, adaptability, and ability to learn. These are applied by business developers, programmers, emergency responders and counsellors. The third skill set is technological, and includes advanced IT skills, data analysis, engineering and research. These are skills applied by software developers, engineers, and robotics and scientific experts.[204] LinkedIn data shows that four of the top 10 hard skills in demand for 2019 are highly technological, with the top two being cloud computing and artificial intelligence.[205] Given that Arab female students are pursuing science, technology, engineering, and math (STEM) fields, surpassing men in some fields and in many countries, one would expect employment

figures to reflect such progress; however the gender education-employment paradox is very evident in the Arab region.[206]

The World Bank identifies three similar types of skills needed in future markets: advanced cognitive skills (complex problem solving), socio-behavioural skills (teamwork), and skill combinations enabling adaptability (reasoning and self-efficacy).[207]

Therefore, the key to analysing the positive and negative impact of 4IR on employment boils down to studying the types of skills augmented by new advances in technology, and the types of skills needed to develop or use new technologies. The challenge is characterizing the exact employment skills needed in different sectors, since the impact is not limited to specific sectors as with previous industrial revolutions, but is job/task specific.[208] This requires a detailed knowledge of the skills applied in the various activities of a certain job, the proportion level exposed to automation, and whether this proportion of automation will result in the job being completely eliminated or simply enhanced.[209] In this age, jobs exposed to automation are no longer restricted to routine tasks, but extended to responsive cognitive and clever manual tasks.[210] Therefore, almost all jobs will be affected by automation to varying degrees, but very few occupations will entirely vanish.[211] For some jobs, demand for the non-automatable activities might even increase, allowing focus to shift to acute aspects of the job. For example, it is estimated that mortgage brokers spend around 90 per cent of their time conducting activities related to processing applications which, if automated, can significantly drop. This will not cause the job to vanish, but would instead allow mortgage brokers to focus more on value added customer service and targeted advising.[212] Broadly, the main jobs or skills in demand will be those requiring non-routine tasks, which are not susceptible to automation.

Another aspect of 4IR and employment is related to adjustments in selected sectors. Specifically, there are areas where adaptation to the new environment and facts will be significant and painful. There will be a shift in demand as some occupations will be eliminated and others will be transformed into new types of jobs.[213] Historically, many advanced economies and emerging markets have experienced the shift from agriculture to manufacturing and then to services.[214] In the United States, employment in agriculture went from 41 per cent in 1900 to 2 per cent in 2000. For example, in GCC countries, it is estimated that by 2020, close to 21 per cent of core skills will be different than those that dominated the work landscape in 2015.[215]

B. Impact on jobs in the Arab region

Predicting the types of future jobs and the specific skills required is difficult.[216] Furthermore, Arab countries have diverse economic, social, demographic, educational and developmental specificities. Unsurprisingly, there is severe lack of data to conduct a comprehensive and objective analysis of the impact of automation on employment.

To carry this analysis objectively, a detailed standardized and measurable description is needed of the knowledge, skills and abilities required for a job, as provided by O*NET.[217] The Labour Statistics Standard Occupational Classification (SOC) system[218] defines 459 broad occupations, 98 minor groups, and 23 major

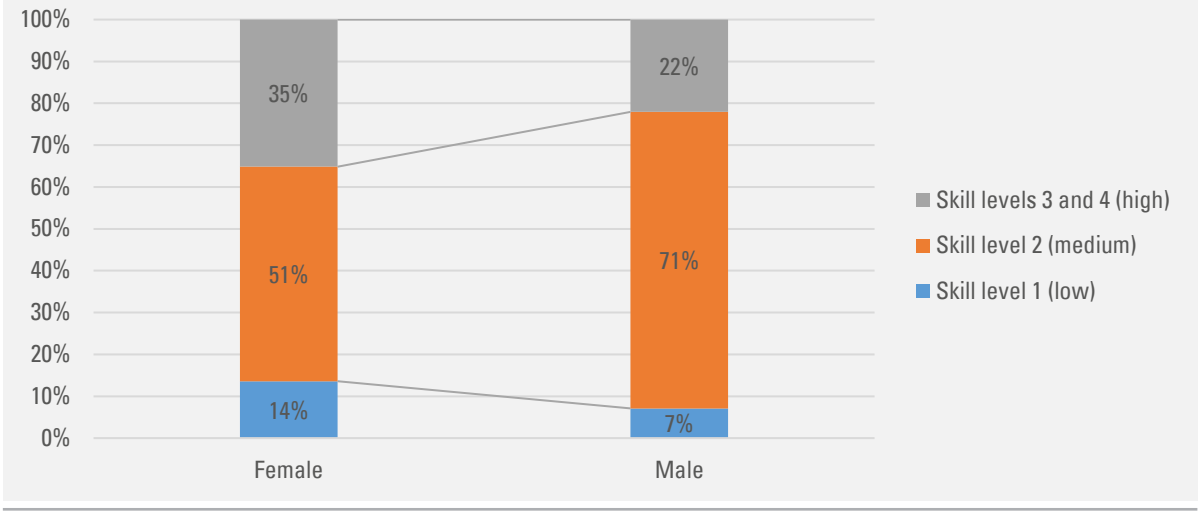
groups. Similar standard classification is provided by the International Standard Classification of Occupations (ISCO),[219] developed by the International Labour Organization (ILO). This precise job definition is required to accurately assess the impact of 4IR on employment.[220] In most Arab countries, such data is limited or is not being collected. The limited statistics reported by Arab countries to ILO are at the SOC 10 major groups levels, which are very broad, or at the (low, medium, or high) level of required skills. Considering ILO data from 2013 to 2017, relevant information is reported by Bahrain, Kuwait, the State of Palestine, Oman, Qatar, Saudi Arabia, the United Arab Emirates, and Yemen.

1. Skill-based analysis

Data sources adopted in this analysis are official estimates, when available. The present report also uses ILO labour force surveys extracted in November 2018.[221] The available data disaggregated by sex were collected under the three skill levels specified using the most recent reported year for each country. Analysis is done only for those jobs that are categorized.

Figure 4 indicates that women are more likely than men to work in the highest and the lowest skilled jobs. This polarity introduces a challenge and an opportunity, given that low and some medium skilled jobs are predicated to be those most likely negatively impacted by 4IR. Given that women tend to work more in high-skilled jobs (35 per cent) than in low skilled jobs (14 per cent), this indicates a more positive outlook. On the other hand, employment for men is expected to be more negatively impacted given that 78 per cent of men work in low and medium skilled jobs compared with 65 per cent of women. These percentages are calculated based on 4.8 million women employees and 27 million men employees. The overall distribution of labour based on this data shows 8 per cent at low level, 68 per cent at medium level, and 24 per cent at high level. When grouping both women and men, about 76 per cent work in low and medium skilled jobs.

Figure 4. Distribution of Arab jobs per skill level per sex

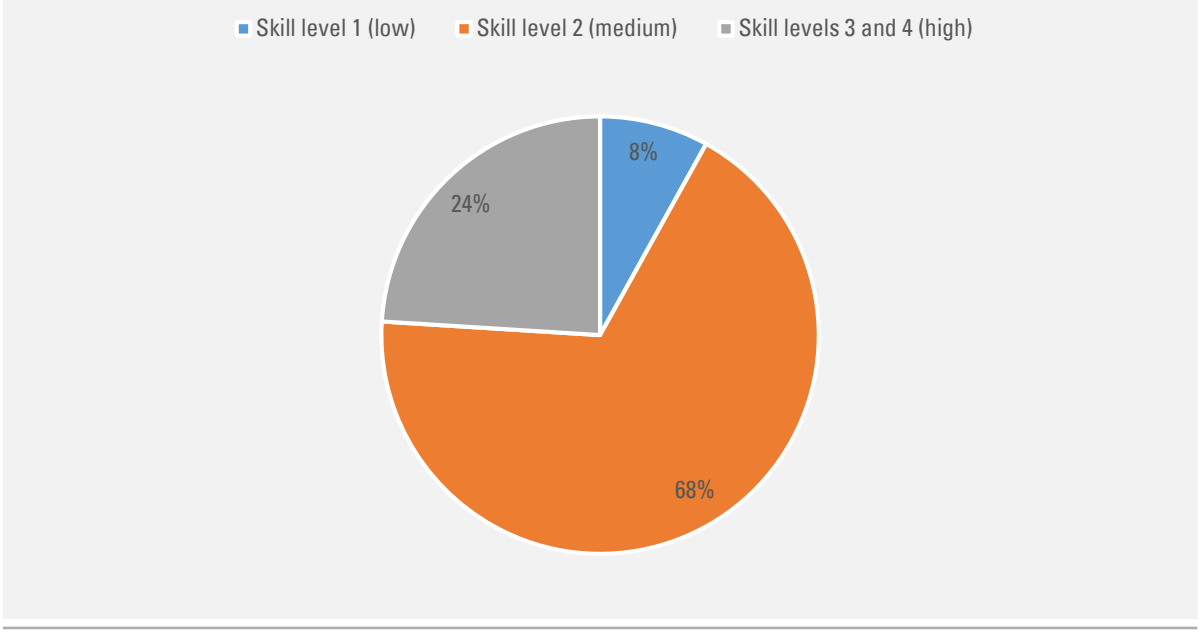


Source: International Labour Organizations, ILOSTAT database.

Considering the overall employment distribution in figure 4, the most common approach from the literature correlates the skill level to the automation ability of a certain job. Hence, it is estimated that 8 per cent (low skill level) of jobs reported in the Arab region are at high risk of replacement, 68 per cent (medium skill level) are at medium risk, and 24 per cent (high skill level) are at relatively low risk of replacement.

A 2017 World Economic Forum study found that 41 per cent of jobs in Kuwait are susceptible to automation, as are 46 per cent in Bahrain and Saudi Arabia, 47 per cent in the United Arab Emirates, 49 per cent in Egypt, 50 per cent in Morocco, and 52 per cent in Qatar.[222] Another 2018 regional study estimated similar figures, projecting that Bahrain, Egypt, Kuwait, Oman, Saudi Arabia and the United Arab Emirates have on average about 45 per cent automatable work activities.[223] This specific study evaluated the automation potential of more than 2,000 work activities from more than 800 occupations. The national results indicated that the potential for automation in present jobs for Arab countries considered in the study are: Bahrain at 45 per cent, Egypt at 48 per cent, Kuwait at 43 per cent, Oman at 41 per cent, Saudi Arabia at 41 per cent, and the United Arab Emirates at 43 per cent, compared with the global average of 50 per cent. The good news is that the model predicted that less than 5 per cent of jobs can be completely automated. This will not be uniform within the region, as discussed later in the present report, since some economies in the region rely more on agriculture, such as Mauritania and the Sudan, and therefore may be more susceptible to automation.

Figure 5. Overall distribution of Arab jobs per skill level



Source: International Labour Organizations, ILOSTAT database.

The potential for automation must also be considered within the context of the dual labour market in several Arab countries, like Saudi Arabia and the United Arab Emirates. For example, in Saudi Arabia, the greatest job losses are estimated in low-wage jobs held by expats;[224] and 90 per cent of automation potential in the United Arab Emirates is also associated with expats jobs.[225]

2. Sector-based analysis

In addition to the employment analysis based on skills classification, a valid yet broad assessment of employment can be carried out per sector. It is important to acknowledge the scarcity of relevant data in the region, and that existing global trends are biased as they lack local context. For example, in general, the Arab region is protected from losses in manufacturing jobs owing to the limited number of such. The Global Manufacturing Competitiveness Index 2016 has only the United Arab Emirates (30th), Saudi Arabia (34th), and Egypt (37th) representing the region within the top 40.[226] This is not expected to improve soon, with Saudi Arabia and the United Arab Emirates projected to drop in rank by 2020. In addition, manufacturing employment as a proportion of total employment is modest, based on the most recent available data for each country.[227]

Table 2. Manufacturing employment as a percentage of total employment in Arab countries

	Percentage of total	Year
Algeria	11.3	2014
Bahrain	12	2010
Egypt	11.4	2016
Jordan	14.2	2004
Kuwait	4.4	2008
Morocco	10.5	2012
Oman	5.6	2010
Qatar	7	2016
Saudi Arabia	7.8	2016
Syrian Arab Republic	14.2	2011
Tunisia	18.5	2015
United Arab Emirates	6.2	2016
Yemen	5.5	2014

Source: United Nations Industrial Development Organization, Statistics Data Portal.

Most Arab countries have a relatively small proportion of labour in manufacturing, with an estimated regional average of 10 per cent. The region can therefore be positioned in a satisfactory spot to leapfrog into the jobs of the future, if an enabling ecosystem and environment are put in place.

Sectoral analysis based on the types of future jobs consistently favours significant social and creative skills in management, business, arts and media, education and health care.[228] The eminent shift is towards high-skill jobs, and away from a high school to a college economy. Regional studies have shown sectoral trends where manufacturing, transport and warehousing have more than 50 per cent automatable jobs, while counterparts in arts, entertainment and recreation, health care and education have an average automation potential of 29-37 per cent.[229] Several studies have an extensive list of sectors with the potential for automation.[230] Machine learning is a specific technology projected onto the region's markets to study its potential impact in the Middle East. It was estimated that the most impacted sectors would be financial services, health care and retail industries.[231]

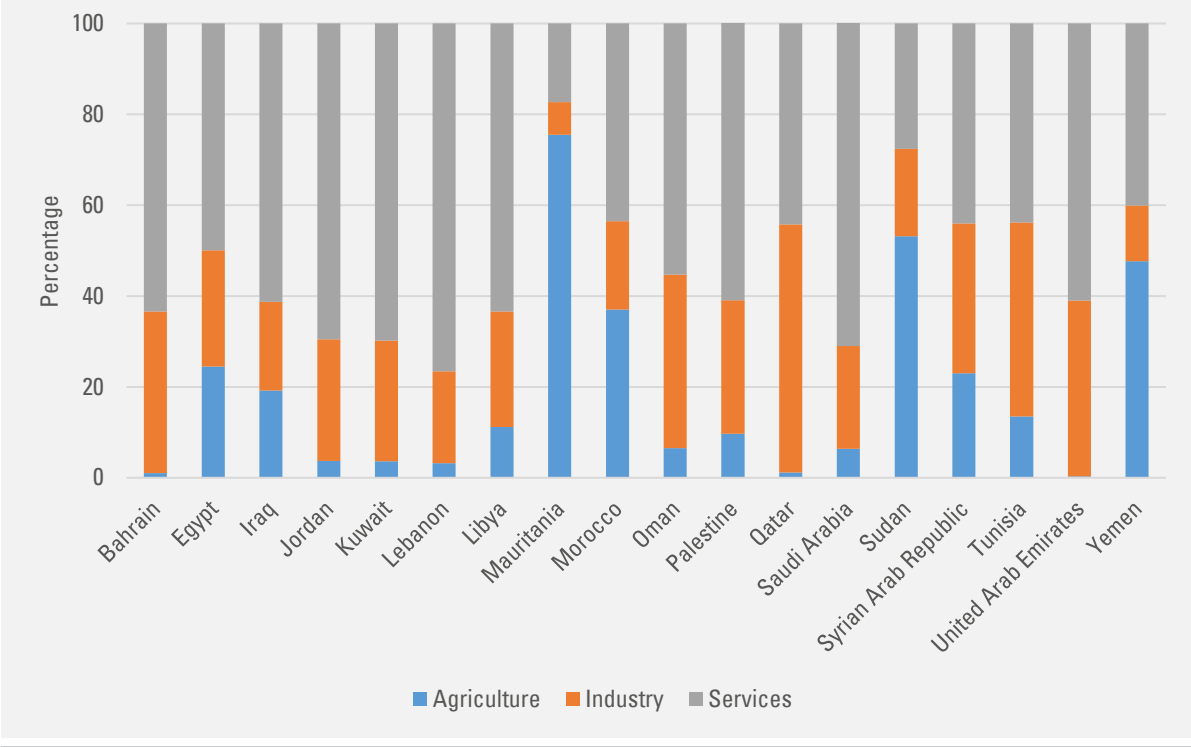
Some examples of sectors being impacted either positively or negatively by 4IR include: journalism, where Associated Press automated the production of financial articles with the support of Automated Insights;[232] media, with several publishing houses such as Dar Assayad in Lebanon closing in the region owing to the digitization of the sector;[233] restaurants, with online ordering and labour automation; medicine, with systems like IBM's Watson which can accurately perform diagnoses; customer service, with chatbots and digital processes; and the financial sector, with automated tellers, online banking and automatic trading.[234] In addition, as artificial intelligence and robotics will be able to perform a wider range of non-routine tasks, jobs in production are expected to be significantly reduced.[235] Again, the jobs with the most heuristics, social intelligence and need for novel ideas are the least at risk. Engineering and science occupations are at low risk owing to the significant creative intelligence needed. But this sectorial analysis can be misleading because although studies show that paralegals and legal assistance fall in the high-risk category, lawyers fall in the low risk category due to the varying types of skills needed for each of these jobs Another study relying on skills analysis to assess the impact of automation on different sectors has shown the following industries listed in the order of most automatable to least automatable: accommodation and food service, manufacturing, agriculture, transport and warehousing, retail trade, mining, construction, utilities, wholesale trade, finance and insurance, arts/entertainment/recreation, real estate, administrative, health care and social assistance, information, professional, management, and educational services.[236]

A regional sector-based analysis can be conducted using data from data.un.org. This data shows the percentage employment per country in agriculture, industry and services. The diversity of the region is evident; for example, the distribution in the three sectors for the United Arab Emirates is 0.3 per cent, 38.7 per cent and 61 per cent, respectively, whereas for Mauritania it is 75.5 per cent, 7.2 per cent and 17.3 per cent. The second observation is that average percentage employment in services is 53.5 per cent in the region. Therefore, if agriculture and industry are more susceptible to automation

than services, it can be seen that on average 46.5 per cent of the jobs in each Arab country are at higher risk of partial automation. This analysis varies between countries, as shown in figure 6. For example, in Mauritania, over 80 per cent of jobs have an elevated risk of being impacted by automation, whereas this number drops to just over 20 per cent for Lebanon. The countries expected to be highly impacted by automation are Mauritania and the Sudan, followed by lower impact in Egypt, Morocco, Qatar, the Syrian Arab Republic, Tunisia and Yemen. The lowest impact according to these estimates is expected in Bahrain, Iraq, Jordan, Kuwait, Lebanon, Libya, Oman, the State of Palestine, Saudi Arabia and the United Arab Emirates. However, this analysis suffers from generalizations; a more detailed analysis is needed within each sector but is not possible owing to a lack of data.

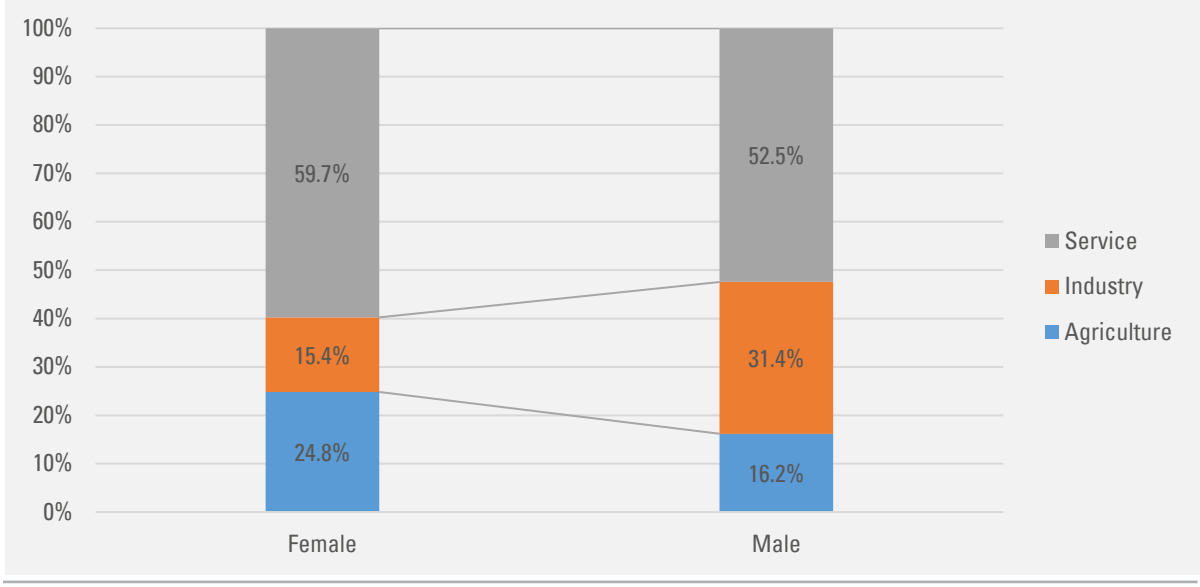
The 2016 data per sector for the Middle East and North Africa, disaggregated by sex, is shown in figure 7. It is clear that a higher percentage of jobs filled by men (47.6 per cent in agriculture and industry) are prone to automation than those filled by women (40.2 per cent). However, the numbers of jobs analysed are considerably different given the low ratio of female-to-male labour force participation rate in the region, at 30 per cent in 2017.

Figure 6. Percentage of employment per sector, 2018



Source: UNdata.

Figure 7. Distribution of Arab jobs per sector disaggregated by sex, 2016[237]



Source: World Bank, Gender Data Portal.

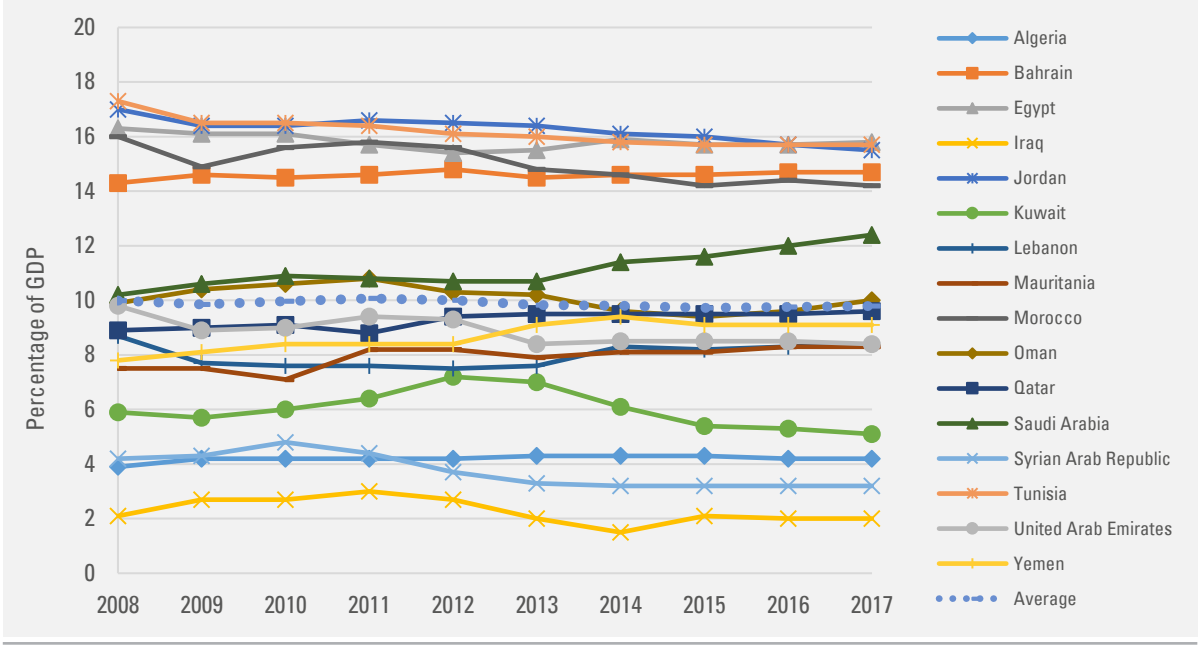
Another sector-based analysis is based on ILO data from Bahrain, Kuwait, the State of Palestine, Oman, Qatar, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates and Yemen. The data shows that 32 per cent are employed in agriculture, construction, manufacturing and mining, with relatively similar percentages among men and women at 33.2 per cent and 29.9 per cent, respectively. Most sectors have similar sex-based distribution within 5 per cent difference, except for construction where the percentage for women is 0.76 per cent versus 11.27 per cent for men, and surprisingly mining where the percentage for women is 22.5 per cent versus 7.86 per cent for men. This indicates that from a sector perspective, women and men face a roughly comparable risk of automation.[238]

This discussion accounts for the opportunities 4IR technologies bring to traditional manufacturing sectors by adding value to existing industries, and improving production and competitiveness. This is much needed considering the contribution of manufacturing (manufacturing value added) to Arab economies, as shown in figure 8.

It is clear that the manufacturing sector contribution to most economies has been stagnant, with an average of 10 per cent over the past 10 years. There has been some progress in Saudi Arabia, but almost a comparable decline in Jordan and Morocco. These numbers are also reflected globally in Arab countries' ranking on the Competitive Industrial Performance Index 2018, as shown in table 3.

Figure 9 is obtained when considering the 2016 distribution of manufacturing activities in the region according to resource-based, low-tech, medium-tech, and high-tech manufacturing.

Figure 8. Manufacturing value added as a percentage of GDP for Arab countries

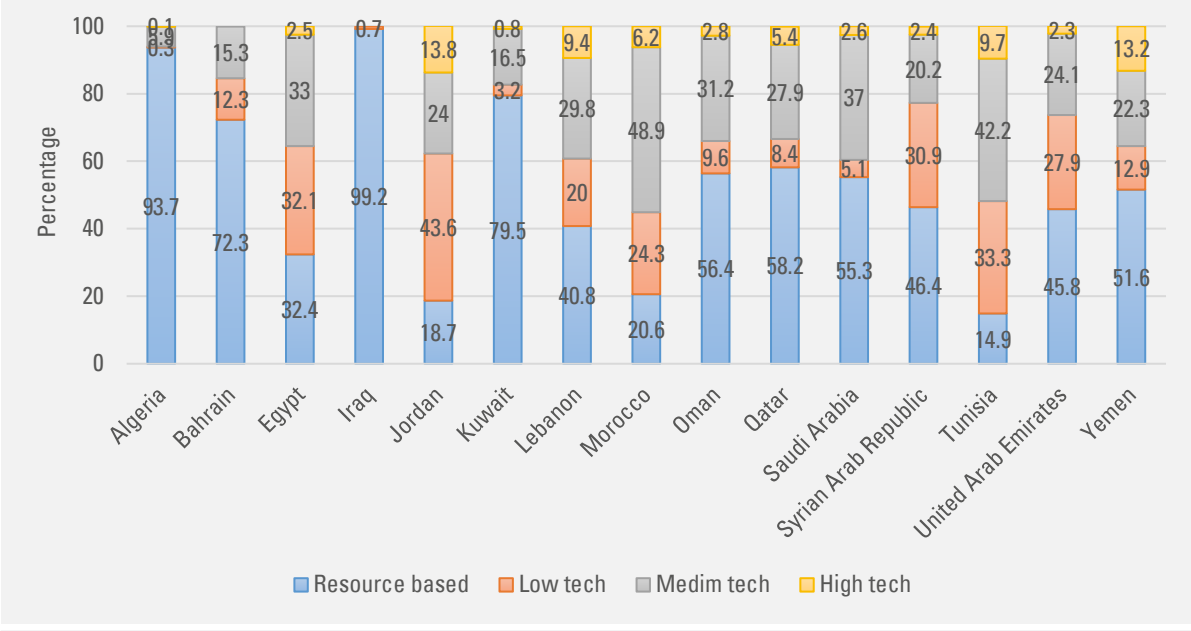


Source: United Nations Industrial Development Organization, Statistics Data Portal.

Table 3. Competitive Industrial Performance Index rankings for Arab countries, 2018

	Rank
Algeria	94
Bahrain	55
Egypt	73
Iraq	146
Jordan	80
Kuwait	57
Lebanon	90
Mauritania	N/A
Morocco	63
Oman	66
Qatar	50
Saudi Arabia	36
Syrian Arab Republic	112
Tunisia	61
United Arab Emirates	41
Yemen	139

Figure 9. Distribution of manufacturing activities for Arab countries, 2016



Source: United Nations Industrial Development Organization, Statistics Data Portal.

The manufacturing sector in most countries is heavily dependent on resource-based and low-tech manufacturing. A total of 10 out of the 15 countries have more than a quarter of their manufacturing in medium and high-tech manufacturing when the two categories are combined. Table 4 is obtained when considering a finer level of composition of the manufacturing sector in the region.

The dependence of the manufacturing sector in the region on natural resources and their byproducts is clear, as mineral, chemical and petroleum products constitute on average 11 per cent, 15 per cent and 24 per cent, respectively, of the manufacturing sectors in the region. The only other significant manufacturing sector is food and beverages which makes up 17 per cent, on average. For example, the export of dates from the MENA region added up to 77 per cent of the world exports in 2016, with Tunisia being the biggest exporter worldwide in value and Iraq being the biggest exporter worldwide in weight.

Other interesting sectors include tobacco products, constituting 9.5 per cent for Jordan, 8.3 per cent for Morocco, and 9.2 per cent for Yemen; and electrical machinery and apparatus, making up 9.7 per cent for Lebanon and 5.6 per cent for Morocco.

Several studies have identified the specific industries in the region with a competitive edge.[239] These include mineral fuels, oil and distillation products, where Arab countries constitute about 30 per cent of world exports but most in the form of crude petroleum oil. This creates an opportunity for upstream products, which can be created in the region. Plastics is another industry where the region is an exporter and can benefit from modernization

to become more competitive. Saudi Arabia exports 4 per cent of the world's organic chemicals, such as acyclic, methanol and industrial ethanol. Methanol is an important commodity for applications in transport fuel and fuel cells. The recommendations have always been for the industry in the region to move up the value chain from raw material to products. This approach is not exclusive to 4IR technologies but, in several cases, can make these strategies more feasible.

The electric and electronics sector is another promising domain, although currently limited in the region. The main activities are in the production of wires and cables (Egypt, Morocco, Tunisia, United Arab Emirates), in addition to other limited success stories like assembling generators and transformers in Lebanon. Given the large number of engineering graduates in the region, this would be an impactful sector to grow as part of 4IR technology development, particularly in robotics, automation and instrumentation.

Other exported natural resources that can benefit from added value are salt, sulphur and stone. Jordan and Morocco are rich in chalk reserves. Jordan, Morocco and the Syrian Arab Republic hold most of the world's phosphate reserves. Nitrogenous fertilizers are obtained from a process using natural gas, which is abundant in GCC countries. This makes the region a key player in the production of fertilizers,[240] which most commonly are a mixture of nitrogenous or phosphorous fertilizers.

Table 4. Composition of manufacturing sectors in Arab economies (percentage)

	Food and beverage	Non-metallic mineral products	Chemicals and chemical products	Tobacco products	Electrical machinery and apparatus	Coke, refined petroleum products, nuclear fuel	Basic metals	Fabricated metal products	Furniture, manufacturing	Rubber and plastic products
Algeria	9.7	2.7	1.8	0	0	80.3	2	0	0	0
Bahrain	11.1	16.8	14.5	0	0	13.8	17	0	0	0
Egypt	11.8	5.8	8.1	0	0	55.1	3.4	0	0	0
Iraq	24.1	21	4.8	0	0	36.6	0	10.4	0	0
Jordan	21.3	9.7	19.3	9.5	0	9.6	0	0	0	0
Kuwait	7.8	6.5	22.8	0	0	40.1	0	3.1	0	0
Lebanon	27.4	14.1	0	0	9.7	0	0	8.2	8.2	0
Morocco	23.2	17	15.9	8.3	5.6	0	0	0	0	0
Oman	11.7	12.1	14.3	0	0	22.1	14.4	0	0	0
Qatar	0	9.5	48.6	0	0	13.3	7.4	6.5	0	0
Saudi Arabia	13	6.2	29.5	0	0	18	0	5.7	0	0
Yemen	44	10.3	0	9.2	0	0	0	11.4	0	5.3

Source: United Nations Industrial Development Organization, Statistics Data Portal.

Pearls, precious stones, metals and coins are significant exports from the region (Egypt, Jordan, Lebanon, Qatar, Saudi Arabia, United Arab Emirates). The Sudan is rich in gold mines, a sector where digital enablers, robotics and automation can contribute high value. Another raw material in the region is cotton (Egypt, Syrian Arab Republic), a sector that can benefit from precision agriculture to scale up production. In 2012, limited vehicle production and export began in Morocco and Oman. In addition, Algeria and Egypt have a long history in automotive assembly. Autonomous or electric vehicle production may therefore be in the region's future, especially given its proximity to Europe. The Arab region has several attractive features that would allow it to grow its industrial sector, such as energy resources, educated and blue collar labour, access to raw material, and a central location.[241] However, a well-planned and closely executed strategy is needed to scale up manufacturing in the region beyond digital marketing and content.

C. Labour force

The employment equation has a supply side that must be analysed to complete the picture. The total population of Arab countries is expected to grow to 444 million by 2030 and to 573 million in 2050, which signals an overall decrease in population growth rates.[242] There is a wide disparity among Arab countries in this regard; for example, Morocco and Oman will have a rate similar to the world average of 4.8 per 1,000 by 2050, Iraq will maintain the highest rate reaching 18 per 1,000, and Lebanon will experience the largest decrease reaching 0.2 per 1,000.[243] The population structure will remain young but with exponential aging rates, where the percentage of the population aged 60 and above will increase from 5.7 per cent in 1985 to 9.3 per cent in 2030, and to 14.9 per cent by 2050.[244] This will also be uneven across the Arab countries, where Lebanon, Morocco and Tunisia will have the highest proportion of older persons.[245] This gives more importance to the right to work and to defending against age-based discrimination in hiring, such as the Elderly Empowerment Project established in Lebanon in 2016.[246]

Another aspect of the supply side for the jobs of the future is the level and quality of educational attainment. When the quality of education is considered, it is revealed that Arab countries ranked low on mathematics and science attainment, according to indicators such as Trends in International Mathematics and Science Study (TIMSS).[247] When companies in the Arab countries were surveyed, they most frequently cited the following skills as being in high demand by 2022:[248]

- Analytical thinking and innovation;
- Active learning and learning strategies;
- Creativity, originality and initiative;
- Technology design and programming;
- Critical thinking and analysis;
- Complex problem-solving;
- Leadership and social influence;
- Emotional intelligence;
- Reasoning, problem-solving and ideation;
- Systems analysis and evaluation.

This is already evident when considering unemployment rates among educated people. For example, the unemployment rate for individuals aged 15-24 with a tertiary education is 29 per cent in Egypt, 26 per cent in Iraq, 47 per cent in Jordan, 61 per cent in Tunisia, 56 per cent in the State of Palestine, and 50 per cent in Morocco. Another revealing number

is total reported employment in research and development in Arab countries at about 128,000, which is less than the Netherlands alone.[249] Regional conflicts have also taken a toll: in the Syrian Arab Republic, about 4 million children dropped out of school between 2011 and 2017.[250] Overall, based on UNESCO data, the expected number of schooling years in Arab countries in 2017 was 11.9 years, while the mean was 7 years.[251]

A recently developed measure of productivity of the next generation of workers is the Human Capital Index (HCI).[252] According to the 2018 HCI, Arab countries ranked (out of 157) as follows: Bahrain (47), United Arab Emirates (49), Oman (54), Qatar (60), Saudi Arabia (73), Kuwait (77), Jordan (79), State of Palestine (82), Lebanon (86), Algeria (93), Tunisia (96), Morocco (98), Egypt (104), Iraq (129), Sudan (139), Yemen (145), and Mauritania (150).

These data indicate a disconnect between education system outcomes and local markets' needs.

D. Jobs of the future in the Arab region

What are the jobs of the future for the region? The uncertainty in answering this question comes from a study by Dell Technologies and Institute for the Future, where they estimate that 85 per cent of jobs in 2030 have not been invented yet. A similar sentiment is echoed in a recent report by the World Bank, which also pointed out that workers of the future will transition between many jobs during their career.[253] LinkedIn data shows that that highest increases in hiring between 2013 and 2017 were in the following jobs (highest to lowest rate of increase):[254]

- Software engineer;
- Marketing specialist;
- Marketing manager;
- Human resources specialist;
- Real estate consultant;
- Writer;
- Lawyer;
- Civil engineer;
- Nutritionist;
- Mechanical engineer.

Hiring decreases were evident for the following jobs in descending order (highest to lowest rate of decrease):

- Accountant;
- Administrative assistant;
- Project manager;
- Salesperson;
- Electrical engineer;
- Customer service representative;
- Sales executive;
- Nurse;
- Civil engineering technician;
- Journalist.

Another data point comes from companies surveyed in the region,[255] which cite the following jobs as having the highest increase in demand by 2022:

- Software and applications developers and analysts;
- Data analysts and scientists;
- Sales and marketing professionals;
- Managing directors and chief executives;
- General and operations managers;
- Sales representatives, wholesale and manufacturing;
- Technical and scientific products;
- Human resources specialists;
- Financial analysts;

- Assembly and factory workers;
- Financial and investment advisers.

In the same survey, companies specified which technologies they were likely or most likely to adopt by 2022. The highest 10 technologies to be adopted in the region were:

1. Big data analytics (91 per cent);
2. Machine learning (79 per cent);
3. Internet of Things (77 per cent);
4. App/web enabled markets (76 per cent);
5. Cloud computing (73 per cent);
6. Augmented and virtual reality (68 per cent);
7. Encryption (62 per cent);
8. New materials (61 per cent);
9. Digital trade (59 per cent);
10. Wearable electronics (54 per cent).

Six of the top 10 technologies and the top three are related to 4IR technologies. Demand from a development and support perspective is evident in artificial intelligence, the Internet of Things, augmented/virtual reality, advanced material, and wearable electronics. Another data point comes from Bayt.com job listings in the region, showing that the information technology sector is closely trailing the oil and gas sector, which traditionally dominated the job market. This highlights the future positive potential of the region's broad technology job market, which is not exclusive to 4IR but is a good proxy indicator.[256]

E. Bottom line on employment in the Arab region

To conclude the employment debate, it can be said that technological advancements 'eliminate jobs, not work'.[257] The question is how to generate demand for required jobs of the future within the region and, more importantly, how should our education systems adapt to better prepare graduates to meet that demand. The region is facing a demand and supply mismatch between market needs and the skills of graduates. Regarding technology development, preparations must be made for the expected demand in programming, artificial intelligence, the Internet of Things, and augmented/virtual reality. Beyond technology development, the sectors expected to realize growth are education and services. Therefore, it is not surprising to expect a rise in demand for augmented reality in education.[258] On the projected shift in demographics, the region must also prepare for expected demand in health care and social services. The main negative effect is that public sector employment will be selectively impacted in agriculture and traditional manufacturing sectors. Within this context, there is an obligation to protect the most vulnerable countries and the most vulnerable within society, and prepare all population segments (older persons, women, refugees, etc.) for the shift already taking place, in line with SDGs 8 and 10.[259] Although some studies expect the burden of the shift in the labour market to impact women more negatively than men, there is still an opportunity to turn things around[260] since future jobs require a mix of digital, STEM, and emotional intelligence skills at which women excel. Complement that with a working environment demanding less physical effort/presence, there is a real opportunity for the region to enhance the career choices of women and close the labour gender gap.[261]

4. Potentials of 4IR for Development Priorities in Arab Countries

4. Potentials of 4IR for Development Priorities in Arab Countries

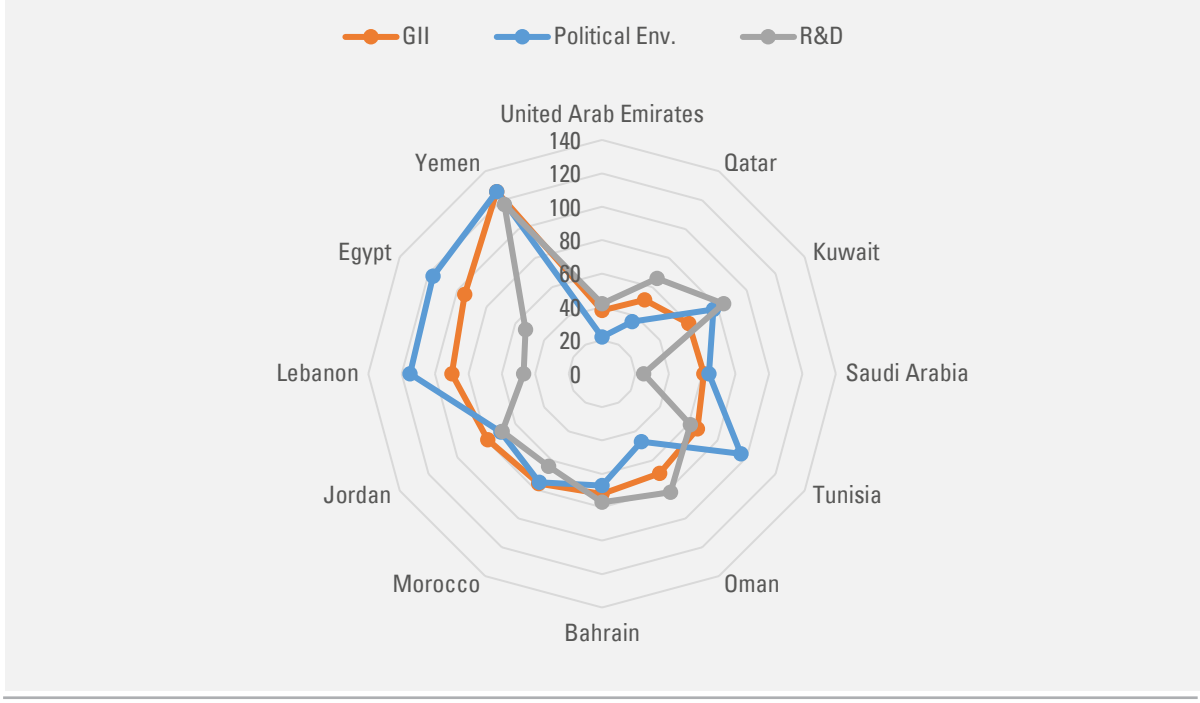
According to the Global Innovation Index (GII) 2018, Arab countries ranked as follows: United Arab Emirates at 38, Qatar at 51, Kuwait at 60, Saudi Arabia at 61, Tunisia at 66, Oman at 69, Bahrain 72, Morocco at 76, Jordan at 79, Lebanon at 90, Egypt at 95, and Yemen at 126.[262]

In addition, no Arab country ranked in the top 20 for the highest combined shares of patents and scientific articles, and none appeared in the top 100 science and technology clusters.[263] As seen in figure 10, GII in the region was more correlated with political environment than research and development indicators, which factor into GII. This highlights the importance of stability in the region for innovation and development to occur.

When assessing the potential of 4IR in the region, a worthy effort is to differentiate the unique impact of locally developing technologies. The opportunity exists not only in the 'Arabization' of content technology, but also in 'localizing' technologies addressing unique problems and challenges that consider the local cultural, political, social and legal contexts. Most regional technology success stories are limited to the adoption of a solution for the region, such as Souq.com acquired by Amazon for more than $500 million,[264] and Careem that reached an agreement with Uber to acquire it for $3.1 billion, consisting of $1.7 billion in convertible notes and $1.4 billion in cash. The acquisition of Careem is subject to applicable regulatory approvals. The transaction is expected to close in the first quarter of 2020.[265] The success of such local initiatives can be partially attributed to solving a local challenge such as Careem accepting cash payments in line with regional norms; and Fetchr, the Emirati-based pickup and delivery service that uses mobile phone GPS to identify pickup location owing to the lack of proper addresses in many Arab countries.[266] However, such technological advances must be approached with caution as they might exacerbate the gender pay gap.[267] Moreover, these celebrated cases are more digital than 4IR technologies built on ICT.

Future trends will identify areas of 4IR that lend themselves most to regional growth. Preferential technological developments are those that are homegrown with decent employment opportunities and a positive impact on sustainable development.

Figure 10. Correlation between GII (2018), political environment and research and development in Arab countries



Source: World Intellectual Property Organization, Global Innovation Index, 2018.

A. Inclusive economic growth

Technological development has historically contributed to economic growth.[268] However, this has not always been inclusive of all segments of society. As discussed in the employment analysis, the challenge is in creating 4IR jobs beyond ICT, advancing education systems to prepare young people, and reskilling for displaced jobs and the ageing population. This is important not only from an employment perspective but also for development.

The concern, however, is that income inequality globally has increased since the First Industrial Revolution. In 1820, Western countries' average income was 1.9 times that of other countries. By 2000, this factor grew to 7.2 times. This is attributed in part to adoption of technologies rather than development.[269] The situation is aggravated by a lack of competitiveness in local manufacturing and globalization, where countries end up importing 'deindustrialization' and widening the economic growth gap. This was highlighted previously in the Global Manufacturing Competitiveness Index 2016 where only the United Arab Emirates (30th), Saudi Arabia (34th), and Egypt (37th) ranked within the 40 industrial countries.[270]

However, the shift in the economy from traditional manufacturing provides the region with an opportunity to catch up with the rest of the world. This is key for achieving inclusive and sustainable development beyond digital

towards a more inclusive and balanced 4IR economy.[271] One success story of productive employment creation in the new digital industry is the Dubai Internet City (DIC), which demonstrates the potential for growth from an ecosystem perspective. DIC has grown into a network of 1,600 businesses in the Internet of Things, AI, cloud and robotics since opening in 1999.[272] Another successful example is the Beirut Digital District (BDD), which emerged out of the war-torn part of Beirut.[273] In a relatively short time and against all odds, BDD became a tech hub housing 130 tech startups, service providers, incubators, media and construction companies and corporations employing over 1,400 young talents. According to BDD internal data, tech companies include those focused on data science (8 per cent), ICT (16 per cent), and several healthtech, augmented/virtual reality, and fintech startups. Smart Village in Egypt is a similar high-tech business district, with several national and multinational tenants operating in the technology domain.[274] When looking at the issue of inclusive economic empowerment under 4IR, it is vital to highlight the gig economy, also known as the platform, sharing or collaborative economy. It refers to labour market activities that are coordinated via digital platforms. Companies operating these platforms act as intermediaries, enabling purchasers to order a timed and monetized task from an available worker, usually taking a fee or commission when the service is paid for or completed. Workers take on 'gigs' without any guarantee of further employment, and they are invariably classified by gig economy companies as independent contractors rather than employees. The operating models of gig economy platforms can be divided into 'crowd work' and 'on-demand work'. The former refers to tasks that are commissioned and carried out virtually, via the Internet. Service purchasers advertise specific tasks on platforms, which can then be matched to suitably skilled crowd workers located anywhere in the world. In this model, the crowdsourcer and the crowdworker rarely experience face-to-face interaction. 'On-demand work' refers to tasks carried out locally, with the purchaser and the provider in physical proximity. These tasks are generally organized via mobile platforms, by companies that set the terms of service and have some role in worker selection and management. In some contexts, notably in poorer countries, workers also engage with work platforms using lower-tech methods, such as text messages or phone calls instead of via a smartphone app.[275] The gig economy constitutes a boon to women and contributes to increased economic empowerment. It is imperative to grasp the concept that women professionals opting for gigs are not freelancers, part-timers or not corporate-job ready. Rather, the gig ecosystem positions them as subject-matter experts with the desired knowhow to successfully execute assignments. The gig economy has created a new world of opportunity, especially one that has resonated with women around the world due to several factors, namely flexibility and freedom, equal and rewarding pay, upskilling and hyper-specialization.[276]

With increased focus on investment in the gig economy, more individuals are looking to provide their services as freelancers because of flexibility that this offers them. The United Arab Emirates has also recently simplified the process to set up small and medium enterprises, which will help entrepreneurs to be their own sponsor for immigration purposes. Free zones have become much more accommodating to the concept of freelancers, and contractors can set up their own businesses to render services to other companies.

For example, Twofour54, a media and entertainment free zone in Abu Dhabi, and Dubai Creative Clusters (formally known as TECOM) free zone in Dubai, accommodate freelancer arrangements and have numerous freelancers available for hire who are registered through their databases. However, work outside the free zone is not permitted and, as such, there is a limit as to how far this approach can be adopted within other free zones or onshore.[277]

In addition to digitization, which underlies several 4IR technologies, 3D printing is levelling the manufacturing ground. In one case, 70 per cent of those surveyed believe that 3D printing will move manufacturing closer to demand.[278] In addition to 3D printing, robots will play a role in redistributing manufacturing because once robots reduce the cost of existing manufacturing processes, companies will start moving manufacturing closer to consumers.[279] Data show that return on investment for robots is dropping: 1.7 years for auto robots in China, less than a year for metal manufacturing in Germany, and 195 days for Universal Robot's co-bot.[280] This has resulted in several examples of manufacturing relocation in the world: Adidas used 3D printing to establish 'speed factories' in Germany and the United States, and Philips Electronics relocated production from China to the Netherlands.[281] A regional example is the design and manufacturing of 3D printed aviation parts in the United Arab Emirates for Etihad Airways.[282]

The challenge is to scale these opportunities and to encourage growth. This requires Governments to promote efforts and programmes, not just policies, to attract and support production in digital and modern manufacturing. Governments must work on elevating barriers to investments, invest in establishing specialized technology hubs, and facilitate access to markets. Governments must also invest in infrastructures of the future to catalyse the adoption of future technologies. These include communication, transport and renewable energy capable of supporting technological adoption in a scalable way. In addition, Arab Governments must work on attracting their expats who have acquired this experience elsewhere in the world. At the social level, the World Bank is calling for enhanced social protection, investment in early education, and human capital development.[283]

B. Efficient recovery and reconstruction

The Arab region has been cursed with lingering crises and devastating conflicts. Libya, the Syrian Arab Republic and Yemen are suffering from years of devastating conflicts; Iraq and the Sudan are in recovery mode avoiding cyclic possibilities; the State of Palestine remains under occupation; Algeria, Egypt, Jordan, Lebanon and Tunisia are have been affected by the shockwaves. Millions of refugees are suffering with no positive prospects.

Several of these conflicts had economic factors as a root cause, which highlights the hopes riding on 4IR in alleviating or avoiding some of the suffering through economic development. In addition, the impact of 4IR is expected in areas of response and recovery. There are several examples of innovations being used to respond to crises. ICT-based payments, marketing, commerce, information, health, and education can facilitate more efficient recovery and reconstruction of communities and cities. Nano-based membranes can make safe water desalination practical and affordable. Localization of reconstruction material can

jumpstart industrialization and sustained employment. One such example is the Ghata project in Lebanon, which received an international human rights award for bringing shelter and education to informal settlements, reaching over 5,000 young refugees annually.[284] Although the project is more related to design innovation, such projects highlight the interdisciplinary nature of the challenges facing the region. Another example, more related to 4IR, is the 3D printing of limbs. It is estimated that the Syrian conflict has left 30,000 with lost limbs.[285] Al-Mowasah Hospital in Amman has been working with Doctors Without Borders to provide 3D printed prosthetics for Syrian refugees.[286]

Another promising 4IR technology for reconstruction is 3D construction. Although the technology is still in its infancy and has not been demonstrated effectively at scale, there is hope that this technology will be able to accelerate the reconstruction of cities especially with rapid manufacturing of housing accessories.

Responsible reconstruction considers the balance between modernizing infrastructure to support future technologies and preserving historical heritage. This requires multi-stakeholder efforts, including urban planners, historians, architects, environmentalists and engineers; in addition to policymakers and local representatives. If planned and executed well, reconstructed cities can leapfrog into the efficient smart cities of the future embracing the Internet of Things and renewable energy while accounting for sustainability. These cities can become the model cities of the future and the live testbeds of new technologies. Such initiatives will attract leading tech companies globally to partner and support such living labs. Effective planning and efficient returns will depend on supporting evidence supplied by big data, spatial data analysis, and other ICT enabled systems. Clearly, these initiatives come with privacy and security concerns, which need to be properly managed and controlled.

C. Women's empowerment

Progress has been made over the past 50 years in closing the gender gap in the Arab region,[287] as reflected in health indicators and access to education.[288] However, a gender gap still exists. For example, women represent a small percentage when it comes to leadership positions in academia and the public and private sectors, and have limited participation in decision-making processes.

ICT has helped alleviate some of the challenges faced by women in the region, such as access to information, connectivity, remote access to health services, safety, access to education, and access to support networks. However, several barriers remain to gender equality in innovation and technology, including the following:[289]

(a) Limited market development of innovations that meet women's needs;
(b) Gender-blind innovation;
(c) Under-representation of women entrepreneurs;
(d) Perceived high risk of investing in innovations for women.

The aim is for 4IR to narrow the gender gap and for women to play a role in advancing this progress. Data show that startups founded or co-founded by women receive less investment than those established by men: $935,000 for women and $2.12 million for men

entrepreneurs, on average. However, revenues on average are higher for women-established startups at $730,000 than men-established ones at $662,000.[290]

The Global System for Mobile Communications Association estimates that closing the gender gap in mobile phone ownership can open a $170 billion worldwide market by 2020.[291] However, over 1.7 billion women in low- and middle-income countries in 2015 were not mobile phone owners.[292] Another market estimate is that women's participation in the workforce can contribute $2.7 trillion to the Middle East economy by 2025.[293] Fortunately, there is some good news coming out of the Arab region in this regard. One survey shows that women have founded or are leading one in three startups in the region, which is a higher percentage than in Silicon Valley.[294] Although these startups are not only 4IR focused, this shows the overall potential for progress.

This is a critical resource for regional growth when the skills needed in future jobs are considered. Social interaction, communication and empathy are all social skills at which women excel and can lead the region's workforce towards closing the gender gap, especially when coupled with required technical skills.[295] This can be accelerated if the proper support systems are in place locally. One such example is the All Girls Code initiative in Lebanon, providing mentorship and networking opportunities.[296] Another larger initiative is the Women in Technology for the Middle East and North Africa.[297]

The 4IR technologies will level the playing field for women in several sectors, because advances in robotics will reduce demand for labour intensive jobs and assistive devices will eliminate men's physical strength advantage.

Another technology that can play a role in assisting and empowering women are wearables. Wearing devices which can detect, report and support to fight against gender-based violence or bullying will contribute to deterring such abuse.[298] Such products are already commercially available, including Revolar and Nimb.[299] New technologies, especially AI, are playing a key role in increasing women's access to help for survivors of violence, given the high prevalence rates of violence at the global and regional levels. For example, in Thailand, a chatbot called Sis Bot was developed to provide a holistic approach to help victims from the start to the end of the justice process. It provides round-the-clock information services for survivors of violence, accessible through their mobile device or a computer. For instance, a woman facing domestic violence can message the Sis Bot via Facebook Messenger and it will immediately respond with information on how to report to the police, how to preserve evidence, and what support services or compensation they are entitled to by law. In Thailand, according to the Promotion of Family Institution Development and Protection Act, the maximum penalty for committing an act of domestic violence is up to six months imprisonment or a fine or both. The court may also order the offender to pay additional money as reparations to the survivor. In this case, the social impact of AI is of high importance. It helps in demystifying the justice system, and enables women to understand what to expect when navigating the system which is usually perceived by survivors as complicated and intimidating. It also has the capacity to assist police investigations and provides survivors with information on how they can best preserve evidence to assist the investigation. It is envisaged to link Sis Bot with other existing services to support survivors, such as shelters, counselling services and

further legal support.[300] Various good practices from the region show that new technologies are being used to raise awareness on violence, report unsafe spaces, and track women and girls' safety, among other things.[301] For instance, in Tunisia, SafeNes[302] is a mobile application that increases awareness and connects victims with specialized non-governmental organizations. It allows users to report violence and designate a trusted person to track their movements if they do not feel safe. In Egypt, StreetPal[303] is an application aimed at providing girls and women with much-needed information on violence, and empowering them to take a stand while providing options for survivors. Regarding reporting unsafe spaces, in Egypt, where a high percentage of women have been exposed to sexual harassment, a real-time violence mapping tool called HarassMap[304] receives reports of sexual harassment through SMS messages and uploads them in real time to a map that shows where sexual harassment is happening in Cairo. In Morocco, Finemchi[305] which means 'Where am I going?' is addressing sexual harassment in public spaces by proposing places that are safe for women. Through this application, places are reviewed and rated depending on how female friendly they are in a bid to reclaim public spaces. The goal of this application is to help women be safe in shared spaces, and to encourage businesses and establishments to better accommodate women. These practices help women stay away from public spaces where harassment is happening and take safer decisions related to their movements. It also publicly encourages owners of restaurants and other places to better accommodate women, and government officials to tackle harassment hotspots. In Morocco, Securella[306] is a mobile application developed to allow women to trigger an alarm when they feel at risk. It connects women in danger with agents for immediate intervention and offers users different 'triggers', tapping once when they feel unsafe in a determined area, and three times when they are in actual danger and need an agent to intervene.

Just like ICT mitigated some social barriers for women in the region, 4IR technologies will further empower women owing to increased demand for social and emotional intelligence.[307] There are different positions in the literature on the impact of AI on gender stereotypes. While, some argue that 4IR might contribute to eliminating gender stereotyping all together,[308] a recent report argues that by naming voice assistants with traditionally female names like Alexa and Siri, and rendering the voices female-sounding by default, tech companies have already preconditioned users to fall back upon antiquated and harmful perceptions of women.[309] It also argues that tech companies have failed to build in proper safeguards against hostile, abusive and gendered language. Instead, most assistants, like Siri, tend to deflect aggression or chime in with a sly joke. Siri's 'female' obsequiousness – and the servility expressed by so many other digital assistants projected as young women – provides a powerful illustration of gender biases coded into technology products that are pervasive in the technology sector, such as gender-imbalanced technical teams and gender gaps in digital skills education.

D. Sustainable and responsible development

There is a lot of hope riding on 4IR technologies to help achieve the SDGs more efficiently in Arab countries.[310] This is evident in the Arab Strategy for Scientific Research and

Innovation,[311] and the Doha Declaration on the Implementation of the 2030 Agenda for Sustainable Development,[312] which calls for a plan on science, technology and innovation in the Arab region. This was reaffirmed by ESCWA member States in the resolutions adopted at the thirtieth ESCWA session held in Beirut in June 2018,[313] one of which states the following:

> *We state our firm belief that technology and innovation are key enablers of the 2030 Agenda and can provide creative solutions to achieve people-centred, sustainable and inclusive development. We are convinced of the need to place technology and innovation as pillars of transformation in national development plans, to maximize benefits and minimize threats from technological disruption, in full consideration of local resources, capacities and constraints.*

The adoption and development of 4IR technologies is key to the successful diversification and sustainability of Arab economies.[314] However, quantifying such an impact is challenging, particularly given the lack of relevant data, therefore most of the discussion is qualitative in nature.

1. Water, energy and food

ESCWA recently published a comprehensive report on technology opportunities for sustainable development in Arab countries.[315] One such area is precision agriculture, targeting the water-energy-food (WEF) nexus. The development and adoption of biotech-based fertilizers and seeds, the Internet of Things, robotics, drones and AI in agriculture can have a significant impact on optimizing food production, while reducing resource consumption and the use of pesticides. Such technologies can optimize irrigation, yield and pesticide use by considering multiple factors, including weather, soil conditions, and historical data. Pure Harvest in the United Arab Emirates is using high-tech greenhouses to increase productivity and reduce water and energy needs.[316] Another 4IR technology in this context is AI, which is used in projects like H_2O Maghreb to build the capacity of water management professionals in Morocco and other Maghreb countries.[317] More importantly, nanotechnology has significant potential for improving the efficiency and reducing the energy demand of desalination and water treatment processes.

There are several initiatives in the region targeting renewable energy technology development and production. One notable experience is that of Morocco, which used to import 95 per cent of its energy. Currently, about a third of that is being generated domestically using renewable sources. Morocco is also planning the Ouarzazate Solar Complex, Africa's largest solar power plant.[318] Another record-breaking power plant is the concentrated solar power facility in Mohammed bin Rashid Al Maktoum Solar Park in the United Arab Emirates.[319] Such initiatives are not only key to sustainability but also contribute to local employment. In Lebanon, it is estimated that 4,000 green jobs can be created by 2020 by deploying renewable energy systems.[320] Nanotech and new material can play a role in such technologies such as in improved efficiency, coating, storage, and life-expectancy of systems. This is particularly important in nanotechnology for next generation solar panels, with improved efficiency and self-cleaning surfaces.

In addition, robotics play a key role as shown by Enerwhere, a distributed solar utility that uses

robots to clean solar panels, which improved efficiency and reduced water consumption.[321] Another profitable perspective of technological progress is demonstrated by RecycloBekia, an electronics waste recycling and safe data destruction services company in Egypt.[322]

2. Care for older persons

Another aspect where the Internet of Things and robotics can play a role is in care for older persons. Changing demographics in the region and ageing populations in several countries have reduced the number of family members able to deliver old-age care.[323] One country development indicator is the ability to 'age in place' and maintain mobility. This is where advances in the Internet of Things, assistive technologies and robotics can help support caregivers by providing monitoring, emergency response and care. Biotechnology and 3D printing of organs will also have a profound impact on life expectancy and quality of life. Another important technology in this mix is autonomous vehicles, which would allow older persons to maintain independence and mobility.

The impact of autonomous vehicles in the region will be broad and multi-faceted, including a decrease in accident rates and congestion, and a reduction of carbon dioxide emissions.[324] The United Arab Emirates is planning for a quarter of its residents to use autonomous vehicles by 2030, which could save up to $6 billion and reduce accidents by 12 per cent.[325] As discussed previously, Oman, Qatar and Saudi Arabia are also embracing autonomous vehicles. This is seen as an area where the region can leapfrog from challenging driving conditions in cities to the future of mobility.

3. Evidence-based policymaking

Data is both a byproduct and enabler of 4IR technologies. Some argue that the oil of the future is data. It is estimated that 2.7 million emails are exchanged in one second, and more than 74,000 YouTube videos are watched. Autonomous cars are expected to generate 4,000 gigabytes of data for each hour of driving. Seven of the top 10 private companies globally are data driven.[326] This highlights the value of data and data protection. In the region, Bahrain, Egypt (draft), Iraq (draft), Lebanon (recent), Jordan, Kuwait, Morocco, Oman, Qatar, Tunisia, United Arab Emirates and Yemen have data protection and privacy laws.[327] If utilized properly with AI, regional data sets can contribute to improvements in various domains, including policymaking and planning for health care, environment, law, education, transportation and governance. Data plays a critical role in the policy arena as it provides evidence for decision-making, which not only reflects present situation but further aggregates on past trends and predicts future scenarios with a high degree of accuracy. To showcase the criticality of data in taking directed and informed decisions, the World Bank undertook a study on the issue.[328] Moreover, UN Women and the United Nations Global Pulse stress the importance of big data and analytics in improving the lives of women and girls, highlighting several cases from around the world to support and empower women.[329]

4. Response to natural disasters

Natural disaster prediction and response is another area where 4IR technologies will excel. AI and big data analytics already play a key role in management and preparedness for natural

disasters, and in mitigating climate change through the prediction of weather events from cyclones hitting Oman and Yemen[330] to sandstorms travelling from North Africa to the Gulf.[331] Robots and drones are already being developed for rescue operations on land and under water. These are key advancements since several Arab countries are susceptible to earthquakes, floods and sandstorms.[332]

5. Cultural support

Augmented reality (AR) will play a key development role, with several applications relevant to the Arab region, such as enhanced educational experience and supply chain. One regional constraint that AR can improve is goods delivery in the absence of a proper address system.[333] In addition, the use of AR will be significant in smart cities to facilitate everyday life with seamless access to real-time information and intuitive interaction with the surroundings. AR is also being integrated in heritage sites and museum experiences to highlight heritage, as in Louvre Abu Dhabi and in museums in Saudi Arabia, and at events being prepared for Dubai Expo 2020.[334]

5. Possible Threats of 4IR in Arab Countries

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In 2018, in his strategy on new technologies, the Secretary-General of the United Nations indicated 4IR technologies' great promise but also their intentional or unintentional negative effects. He recalled that just as social networking brought people together and enhanced free communication, it also became a platform for hate speech and terrorist activities. Just as AI and robotics provide improved productivity, they can also increase inequality within and between countries. Similarly, the Internet of Things provides several economic opportunities while posing risks to privacy and security.[335] Mobile devices opened up numerous opportunities, but they can also harm relationships, distract operators and threaten public safety, and be harmful to health.[336] Given that most Arab countries have reported the highest mobile adoption rates worldwide, this raises several concerns. For example, in Saudi Arabia, 68 per cent of surveyed users indicated that they use their phones within five minutes of waking up, and 30 per cent of Saudi students use their phones eight hours per day. The impact of such high levels of use remains unclear. A more troubling trend is the use of phones while driving. In the region, one out of five men admits to using the phone while driving, which is seven basis points more than women in the region, and four basis points above the rest of the world.[337]

When it comes to 4IR technologies and public opinion, the Arab World Online 2017 report shows that 71 per cent of Internet users in 22 Arab countries are concerned about AI and privacy, while 46 per cent are concerned about AI and loss of jobs.[338] The report highlights several concerns related to most 4IR technologies.[339]

A. Security

There are lingering concerns about the potential impact of 4IR on security in the region, both cyber and physical, which extend beyond data and system security. For instance, consider automated border controls where facial recognition is used to validate identity, as in Dubai's new Smart Wallets and One Gate. In addition, when 71 per cent of Emirati mobile users use fingerprint to unlock devices, there is a concern that sophisticated hackers can capitalize on the existence of biometrics databases across several industries to conduct multisector exploitations using stolen or forged biometrics.[340] Another security concern is coupled with the proliferation of Internet of Things devices, such as networked cameras that are widely deployed in several cities in the region. These security enforcement devices can become themselves a target or a tool for attacks.[341]

Historically, the region had been targeted by sophisticated attacks, including a complex cyber-espionage toolkit targeting systems in the Middle East in 2012, primarily in Lebanon.[342] PricewaterhouseCoopers estimates that Arab countries are targeted with 6 per cent more cyberattacks compared with the rest of the world.[343] However, the concern with 4IR goes beyond data and financial damages to losing

lives. There have been reports of hacks to pacemakers, glucose-monitoring and insulin-delivery systems, neural implants, and smart prosthetics.[344] When robots and drones are added to the mix, we end up with autonomous weapons that take us past Isaac Asimov's Three Laws of Robotics in his short story *Runaround*: a robot should not harm a human being; a robot should always obey a human being; and a robot should defend itself so long as it did not go against the first two laws.[345] Although this was a fictional story, these laws have for the most part governed the development of robotic systems. However, several Governments are openly and secretly engaging in developing autonomous and semi-autonomous weapons. Given the region's numerous conflicts, there is a real concern that it will be used as a testing ground for several of these weapons.[346] To a lesser extent, another concern is the engagement of regional researchers and industries in the development of such weapons, as has happened in other countries.[347] A lack of regulations and monitoring of such activities in the region opens the door for outsourcing such development to the region, thus raising numerous ethical and moral considerations.

There is a need to train developers in the region on secure programming and best practices, so as to develop secure regional software products and applications. In addition, without a regional well-trained cohort of engineers and technicians able to secure infrastructures and facilities, there is a significant and real concern not only from individual hackers but from adversary countries. Initiatives such as the Saudi Federation for Cyber Security and Programming[348] can be adopted throughout the region to establish advanced capabilities in cybersecurity. Moreover, preparedness is vital and achieved through the establishment of local computer emergency response teams (CERT), such as the Oman National CERT,[349] and through regional collaboration to establish a regional CERT, as in most regions of the world.[350] Oman ranks fourth worldwide on the Global Cybersecurity Index 2017, with Egypt and Qatar ranked second and third among Arab countries.[351] ESCWA has been leading efforts with the League of Arab States towards a sustained regional process for Internet governance and cybersecurity.

B. Privacy

With increased use of mobile social media and smartphones for navigation and access to information by millions of residents and visitors in the region, there is an evident concern about privacy and safety. However, this goes beyond personal, financial and medical data privacy, surpassing the European Union General Data Protection Regulation.[352] Technology's eyes and ears have unprecedented access to our lives. Robots and connected devices have the ability of direct surveillance and increased access.[353] These connected household items can allow direct access into individuals' lives using their cameras and microphones.[354] Even without direct surveillance, numerous personal and intimate information can be inferred from connected appliances and wearable devices.[355] In some instances, most data can be inferred from one device or service, such as Amazon Echo or Google Home.[356]

This is a growing concern in the region, where more than 20 per cent report that they have a TV that is Internet enabled, about 5 per cent have smart watches, and about 4 per cent have personal cars that are Internet connected. The same survey shows that the majority are concerned about their data and about being monitored. In the Arab region, this concern

extends to State players where technology can be used to suppress freedoms by employing sophisticated surveillance and data analytics systems.

C. Ethics

Robots are no longer only in factories housed within a cage, and classic algorithms no longer only recommend books to read. Robots are in our homes and AI is making life or death decisions. This amplifies and complicates all ethical dimensions that existed with previous technologies, privacy, security and liability. Moreover, this introduces new questions, such as ownership of art developed by an AI algorithm.

The following questions have no ethical answers like: How about an AI algorithm to predict the death of a patient? How about informing the patient of the prediction? Why not inform the insurance company? If an autonomous car injures a pedestrian who is liable: the car owner, the car manufacturer, the software developer, or the AI algorithm designer? How about developing autonomous weapons? What if they are more accurate than human soldiers?

Lack of ethical answers to such questions has already caused controversy, even for giant corporations. Google recently announced that it will not seek to renew Project Maven, a controversial United States military drone AI imaging programme.[357] However, this only happened because of a backlash from thousands of Google employees who signed a petition against the project.

Several organizations are responding to these ethical dilemmas and working on establishing ethical standards. One such effort is led by one of the largest technical organizations in the world, the Institute of Electrical and Electronics Engineers (IEEE). It established the Global Initiative on Ethics of Autonomous and Intelligent Systems, which is working on IEEE P7000 Ethically Aligned Design, a global standard for ethical AI.[358] The International Organization for Standardization (ISO) already has standards related to AI.[359] An interesting relevant ISO standard is the one related to safety requirements for personal-care robots.[360] At the regional level, Arab countries are working on adopting a code of ethics in science and technology. UNESCO is championing the effort by developing a draft of the code.[361] At the national level, Smart Dubai has endorsed guidelines on ethical use of AI.[362]

6. Balanced Roadmap of 4IR Local Implementation

6. Balanced Roadmap of 4IR Local Implementation

A. National technology strategies and policies

The disruptive nature of 4IR technologies necessitates appropriate planning and management. Otherwise, the technology's impact will not be positive overall.[363] Most Arab countries have a strategy related to research and technology that are an integral part of national development strategies. These strategies include the following:

- Bahrain: National Research Strategy (2014-2024);[364]
- Egypt: Industrial Development Strategy (2050);[365]
- Libya: 2020 Vision;[366]
- Qatar: National Vision 2030;[367]
- Saudi Arabia: National Policy for STI[368] and Vision 2030;[369]
- United Arab Emirates: several technology strategies;[370]
- Tunisia: Digital 2020;
- Arab Strategy for Science, Technology and Innovation.[371]

UNESCO has also been working with various Arab countries on developing policies related to science, technology and innovation.[372] Historically, the region has not lacked strategies, but rather implementation and execution. In addition, in the majority of cases there is a lack of data to assess the impact of these policies and strategies on the economy. Even standard data such as education expenditures and research and development expenditures are either missing or not current for most Arabic countries in standard sources, such as the World Bank and UNESCO. One thing is evident from the little data available for Arab countries: government expenditure on education does not exceed 4.2 per cent of GDP on average, and expenditure on research and development does not exceed 0.5 per cent of GDP on average, while military expenditure exceeds 5 per cent of GDP on average.[373]

B. Productive research, development and innovation ecosystems

In 2015, ESCWA began working with Egypt, Lebanon, Mauritania, Morocco, Oman, the Sudan and Tunisia to establish national technology transfer offices (NTTO).[374] This was intended to enhance the linkages between universities, research centres, industry and Government, and to enhance innovation by working on relevant legislations and policies. One of the outcomes of these efforts was the publication of national technology development transfer system reports in 2017, which included detailed analysis of the status of research, and technology development and transfer.[375]

These national reports contain landscape analysis of science and technology mapping covering universities, science parks, incubators,

venture funds, and entrepreneurship initiatives in seven Arab countries.[376] A comprehensive list and analysis of science and technology parks throughout the region can also be found in a recent ESCWA report.[377] Science and technology parks include the following: Bahrain: Technology Park,[378] Jordan: Royal Scientific Society,[379] Oman: Knowledge Oasis Muscat,[380] Saudi Arabia: King Abdul-Aziz City for Science and Technology,[381] Tunisia: Elgazala Technopark,[382] and the United Arab Emirates: Dubai Techno Park.[383] A list of technology focused incubators in Egypt include:[384] Tabbin Institute for Metallurgical Studies Incubator, Mansoura Incubator, Sixth of October City Incubator, Ain Shams Incubator, and Tenth of Ramadan Incubator. Table 5 clusters Arab countries into four groups in terms of innovation policies, institutions and science and technology parks (STPs).[385]

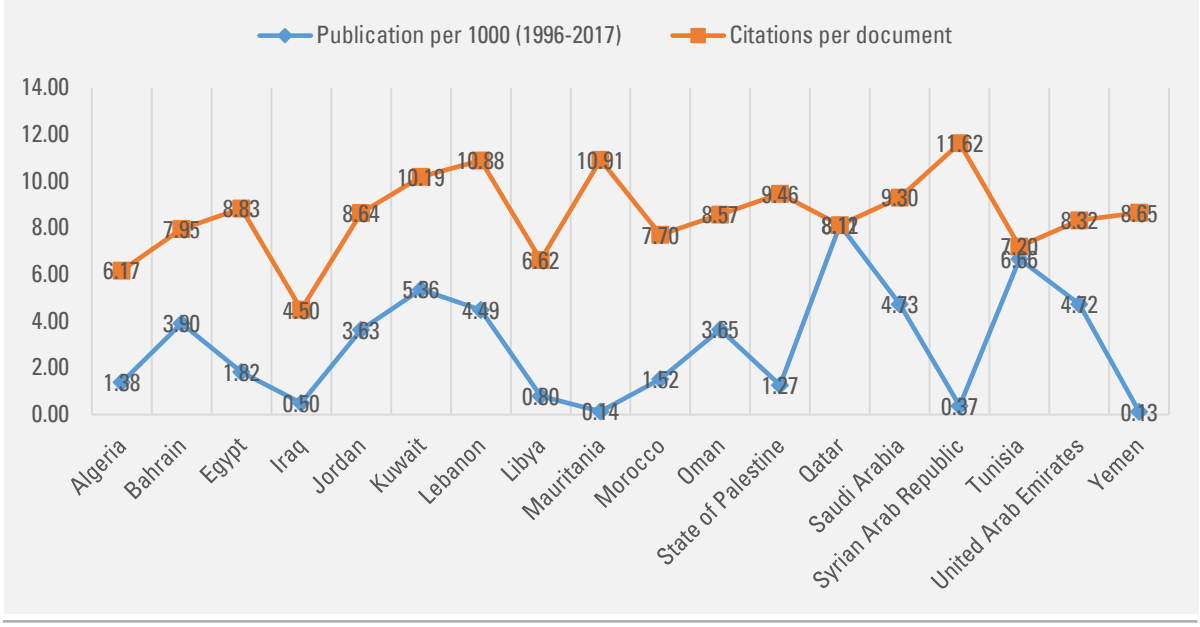
Within this ecosystem, Arab countries' scientific productivity indicators are mixed. Figure 11 shows the publications per 1,000 inhabitants and citations per document between 1996 and 2017 for Arab countries. The number of publications is an indicator of the productivity level, while citations per document is an indirect indicator of impact. The analysis of publication records shows that, on average, citations per document for Arab countries is 8.53. The total number of publications in the Arab region between 1996 and 2017 was 736,514. In addition, publications per 1,000 for Arab countries is about 2.06. Considering selected contributions of Arab countries to the global number of publications shows that the percentage of publications in the areas of nanoscience-nanotechnology, biotechnology-applied microbiology, and computer science and artificial intelligence reach 2.7 per cent, 2.8 per cent and 6 per cent, respectively.[386]

Table 5. Arab countries grouped by innovation policies, institutions and STPs

Group/Countries	Status	Policy and recommendations
Group 1. Tunisia, Jordan, Lebanon, Egypt, Morocco	Mature STPs and policies	Accelerate reform
Group 2. Saudi Arabia, United Arab Emirates, Kuwait, Qatar, Bahrain, Oman	Rich countries enjoying accelerating STPs	Focus on economic diversification and citizens' capacity
Group 3. Sudan, State of Palestine, Algeria	Innovation policies and emerging STPs	Complete the establishment of STPs and collaborate with countries in groups 1 and 2
Group 4. All other Arab countries	Difficult to classify	Holistic review of policies, innovation and research.

Source: ESCWA, Science and Technology Parks: Global Outlook with a Focus on the Arab Region, 2018.

Figure 11. Publications (per 1,000) and citations per document for Arab countries



Source: Scimago Journal and Country Rank; World Bank Database, available from https://data.worldbank.org/indicator/SP.POP.TOTL.

Another indirect indicator of commercialization potential is patents. The USPTO database counts 4,358 patents from inventors in the Arab region from 1976 to the present, while Switzerland reached 24,226 patents over the same period.[387] Although some improvements exist within the region, indicators of both productivity and impact are low compared with the rest of the developed world. However, patents registration is not a true indicator of the level and extent of innovation activities in Arab countries. Patent drafting, searching, registration and protection remain expensive and impractical for most SMEs and local industry and research centres.

To capitalize on regional research and benefit from technological advancements in 4IR, there must be effective technology transfer policies and mechanisms. Based on ESCWA research for Lebanon, Morocco, Oman, Egypt, Mauritania, Tunisia and the Sudan, several recommendations and best practices were revealed to enhance technology transfer in the region,[388] including the following:

- Promote collaboration between universities in the region;
- Establish regional and international networks for collaboration;
- Establish frameworks for collaboration between industry at the regional level;
- Establish legal frameworks to facilitate and protect research and development across the region;
- Encourage investments in technology development;
- Remove importation and procurement barriers for research and development prototyping components and equipment;

- Establish tax incentives for industry to engage in research in the region;
- Establish centres for sharing resources (maker and fab spaces, computing resources);
- Establish a regional investment fund to invest in the region.

C. Socially conscious investments

Socially focused startups are not uncommon in the region, but most are not technology oriented.[389] C3 is an incubator for companies focused on social enterprises,[390] and NYUAD organizes an annual International Hackathon for Social Good in the Arab World.[391] In 2018, the winners included Dawa, an application employing blockchain to tackle counterfeit medicine; Boosala, was designed for refugees to locate missing family members; Huwayeti, which is a blockchain-based application that integrates with the UNHCR refugee registration system; and MedLughati, which allows refugees to communicate with doctors using natural language processing and AI.[392] A similar hackathon was held in Saudi Arabia to address social needs.[393] Some initiatives have focused on empowering the most vulnerable, such as the Startups without Borders, which supports migrants and refugees with entrepreneurial efforts.[394] There are also several initiatives in the region supporting and encouraging socially conscious innovation. For example, the Innovate for Refugees tech competition[395] and the EU Madad Innovation Labs[396] organize international competitions targeted at challenges faced by refugees. The declaration of the Arab Economic and Social Development Summit, held in Beirut in January 2019, launched a $200 million technology investment fund across the region established by Kuwait's foreign minister, with Kuwait and Qatar each contributing $50 million. The fund aims to invest in technological fields with the participation of the private sector, and calls on Arab countries to support this initiative.

Other initiatives in the region are harnessing the power of technology for social good. One such example is the Refugee Open Ware, which aims to enable and empower displaced communities to improve their conditions. This is done through investment, human capital development, and access to resources.[397] Robotics will also play a significant role in the improvement of quality of life of the disabled and older persons. This will be accomplished using assistive robotics, exoskeletons, and other specialized devices.[398] The Internet of Things plays a role by making living spaces and cities smarter, and therefore more accessible.[399] Another example is the use of robotics by Atlab to improve the learning skills of autistic children at the Al Quwain Autism Centre in Dubai.[400]

Technological development must be governed by a human-rights approach. Harnessing the capabilities of 4IR necessitates, now more than ever, adhering and protecting human rights throughout the process.

D. Skilling and retraining: job and labour market restructuring

Given the certainty of labour market restructuring and a shift in the types of skills of the future, the most pressing need in the region is immediate attention to skilling and reskilling. At the job market level, there is a shift from hiring based on credentials to hiring based on demonstrated skills. This brings a shift from just addressing literacy indicators to addressing skills indicators. On the one hand, this raises challenges for universities to quickly adapt to these new realities; and on the other hand, this

means that displaced labour has hope for reintegration through reskilling.

Such reskilling could be facilitated through ICT-enabled platforms like Noon Edu from Saudi Arabia.[401] Although it is not a 4IR-focused platform, it has shown the potential of such platforms, with 1.6 million registered students. If the scalability power of such platforms can be harnessed, it will have a significant impact on reskilling efforts in the region. Another successful programme comes from Egypt is 'Next tech leaders'. It was launched in 2016 by the Egyptian Ministry of Communications and Information Technology, and has already trained 5,000 students in new technologies. Similar initiatives are taking place in Jordan, Saudi Arabia and the United Arab Emirates.[402] On a smaller scale but with an interesting business model is SE Factory from Lebanon, which focuses on skilling in programming.[403]

Another impacted segment of the population is older persons. Egypt, Iraq, Lebanon and the State of Palestine offer courses targeting information technology and computer skills for older persons.[404] A successful initiative targeting lifelong learning is the University for Seniors at the American University of Beirut, established in 2010.[405] Although not focused primarily on technology, it can be a model to follow in reskilling older persons looking to remain in or enter the job market. ICT has made education more accessible and 4IR technologies have the capacity to make education and training more effective. Augmented and virtual reality will play a key role in innovative enhanced delivery methods. This opportunity is already being capitalized on by startups in the region focused on education, and it also a global trend.[406] Another technology impacting education is AI, by providing customized and personalized content and delivery. In addition, AI can provide automated tutoring and support outside the classroom, and can support teachers by automating tasks such as grading.[407] This is not considered a replacement to educators, but would allow teachers to focus more on personal interaction and value-added contributions, thus harnessing the learning facilitation role of academic professors.

7. Key Messages

7. Key Messages

Addressing the challenges of and capitalizing on the opportunities of 4IR require comprehensive multi-stakeholder cooperation. This effort must be guided by common principles, values and objectives.[408] It is evident that the region must function differently to tame 4IR technologies. The region cannot afford to be an observer and recipient of this technological revolution, but rather must contribute to shaping it, especially in localizing its applications within local context and culture. This will require conscious efforts with specific action plans from Governments, the private sector, civil society, academic institutions, and regional conveners such as ESCWA. The Fourth Industrial Revolution is a rare chance to address persistent developmental challenges with efficient and smart solutions. The key messages below are clustered in various categories and omit obvious recommendations that have been set out in many past reports and expert meetings.

A. Governments

Arab Governments are key players in navigating the regional response to 4IR impact and potential. Some have clearly embraced this revolution and are early adopters. Efforts are needed towards initiating and scaling up relevant activities by channelling local capacity and resources into a technology hub, yielding both disruptive and useful impacts.

- National strategies and priorities: National initiatives like the Emirati strategy[409] and proposed ESCWA innovation policy framework[410] are important for building on local resources, existing capacity, and strengths in human capital, and for addressing key local challenges including gender-sensitive strategies. Based on regional mapping and assessment criteria provided in the present report, the following are the most promising 4IR technologies: artificial intelligence, the Internet of Things, nanotechnology, blockchain, and big data. These strategies must be sensitive to the local context, follow a human rights-based approach and engage the private sector in a public-private partnership;
- Funding: Governments need to launch strong and relevant incentives for multinational companies and local productive sectors to invest in localization and development of 4IR technologies, such as the Qatar National Research Fund's cost-sharing programme and the Central Bank of Lebanon's Circular 331.[411] The regional fund established by the Arab Economic Summit held in Beirut in 2019 and managed by the Arab Socioeconomic Fund in Kuwait can take advantage of existing regional mechanisms like ESCWA, AIDMO and ALECSO to strengthen cooperation and create regional technology hubs.[412] Sharing and scaling up regional leading experiences must be promoted, like Masdar City's in clean technology[413] and nanotechnologies for efficient desalination and solar energy. Specific funding opportunities must be created for initiatives which empower

women to enlist their huge potential and tap into new opportunities;

- Global presence: Arab Governments must take part in the ongoing global dialogue and plans on establishing governance structures. An example is the Government Group of Experts on Lethal Autonomous Weapon Systems, and a proposed intergovernmental panel or entities;[414]
- Data: There is a dire need for Governments to adopt an open approach to data access. A regional repository for sex-disaggregated data collection and analysis is recommended, similar to Dubai Pulse.[415] Special incentives and mechanisms are needed to mine data safely to improve health, environment, planning and governance. This must be coupled with effective policies for personal data protection;
- Technology transfer networks: Empower and enable national and regional networks to better link universities, research centres, and industry. Such existing networks include Arab States Research and Education Network and the various national research and education networks (NRENs).[416] Promote institutional policies for linking university and industry through career development assessment ladders;[417]
- Skilling and reskilling: Develop subsidized programmes for reskilling workers with direct employment opportunities at graduation. Incentivize tech companies to be contributors to the reskilling programmes and subsidize volunteer programmes;[418]
- Infrastructure: Governments must ensure that ICT, transport, energy, and water infrastructures are supportive of the ecosystem of the future, and that these infrastructures are themselves 4IR enabled and efficient. The challenge is to develop such large and long-term projects while the technology is still being developed and doing so at a fast pace. Therefore, Governments are called upon to build adaptive and scalable infrastructures able to grow and progress as technology dictates;
- Legislation and regulations: Lawmakers must quickly catch up with the laws needed to protect and mitigate the effects of 4IR. Legislation is needed on cybersecurity, use of autonomous vehicles, drones and robots, among other technologies. The key is to make sure the legislation does not stifle innovation and technology adoption;
- Improve governance: Without transparent and stable Governments, innovation is suffocated. The Corruption Perception Index 2017[419] listed many Arab countries in the top 50 countries. Arab Governments still have a long way to go in battling this obstacle to progress in general, and not only within the context of 4IR. The present report sets out 4IR enablers for more transparent and inclusive governance.

Several of these recommendations were adopted by ESCWA member States in the Beirut Consensus on Technology for Sustainable Development in the Arab Region.[420]

B. Private sector

Arguably, the main catalyst for bringing 4IR to the market is the private sector, in all its branches. In this regard, the private sector must play a significant role in supporting Governments as follows:

- Reskilling: Playing an active role in reskilling efforts by providing expertise and resources. In addition, the private sector must identify the key needs of the market. The present

report indicates key future jobs and related sectors in the Arab region that can harness 4IR technologies for local benefits;
- Remove obstacles to women in leading 4IR applications and development: Future skills are natural strengths that women possess. This might be an opportunity to close the gender gap in the region economically and socially;
- Investment: Support government efforts in investing and using new technologies. The localization of AI applications requires Arabic natural language processing where universities and research centres have the needed support. Purposeful investments that assess solutions to major local challenges are huge investment opportunities to deploy 4IR-based solutions in established local markets;
- Innovation ecosystem: There is a need to continue to create innovation hubs, incubators, and accelerators. In addition, there must be efforts to link the regional private sector to successful 4IR technology hubs around the world, while looking eastwards (for example, China, Singapore, Japan) and westwards (for example, the United States, France, Germany, Canada).

C. Civil society

Civil society in the region has played an important role in development, even in some cases stepping in to address government absence. Civil society is called upon to keep this active role by undertaking the following:

- Reskilling: Taking part in the massive reskilling effort required, especially given that top future jobs are based on soft skills and emotional intelligence easily acquired for all;
- Governance: Be part of governance structures put in place to oversee the impacts of 4IR technologies, especially regarding open data, ethics, privacy and security. Meet demand from multinational corporations to apply AI tools for addressing security and privacy challenges raised by AI and big data;
- Oversight: Civil society must still play an informal oversight role to ensure ethical decisions are being made, the gender gap is addressed, and vulnerable populations are accounted for in planning while being protected. It must also play a monitoring role with regard to environmental, social, and cultural effects. To sustain such efforts, formal frameworks must be established, such as the Future of Life Institute.[421]

D. Universities and schools

Educational institutions in the region must make a leap into the future. Today, it is experiences and skills that are sought after rather than degrees. Universities are losing monopoly on granting knowledge certificates with free access to massive online courses and learning. They are called upon to undertake the following:

- Curriculums and modes of delivery must change to match the skills of the future. More than ever, collaboration is needed between universities, training centres, and employers.[422] This is key to identifying required skills and the market needs. Citi research suggests the two main focuses are on STEM and soft skills.[423] On the delivery mode, the region has several educational startups but still lacks open online courses

in Arabic with broad dissemination. This must be coupled with required changes in regulations in the region to accept online degrees. For public and private schools, there is a need to update curriculums and teaching methods to meet the needs of future learners. Continuing with the old-fashioned methods of delivery and outdated content will have a long-lasting negative impact on future generations. Governments and the private sector must partner to create learner-centred schools for future skills;

- Gender gap: Universities must put more effort into actively recruiting women to STEM fields, both as students and faculty members. Closing the gap at the faculty level is key to the success of recruitment and retention of women students because of the need for role models. The present report shows a well-positioned situation for women leading development in the 4IR era;
- Reskilling: Universities must contribute resources and facilities to support the wide reskilling efforts needed. Universities must share the burden of this reskilling, especially given that they are in the best position to champion it;
- Research, development and entrepreneurship: Very few universities in the region invest significantly or even reward innovation by their faculty. This is at the heart of technological development and must be carried out at an unprecedented scale. Universities must establish a strong reward system for commercialization efforts carried out by their faculty members. They must also encourage and support a culture of entrepreneurship among students. This can be done by establishing accelerators or tech hubs within universities. The present report shows the leapfrogging possibilities for relevant innovation in the 4IR economy.
- In addition, universities must establish research and development centres that focus on developing technologies to address unique global south challenges. This would be a differentiating factor and a point of strength for research and development, as unaddressed challenges might be revealed, and the local context can be capitalized on;
- Graduate degrees: Universities must not shy away from offering graduate degrees up to the PhD level, with proper quality control in place. This is important for populating research centres so as to transform the region into a tech hub in at least one or two areas of 4IR technologies. Candidate areas are nanotech and blockchain, as shown in the present report.

E. Regional organizations

Regional think tanks and policy advisory houses like ESCWA must make use of the recommendations and templates they suggest and promote with Governments and communities. Several of these recommendations echo those set out in the Secretary-General's Strategy on New Technologies.[424]

- Internally: there is a need to assess how best to capitalize on new technologies in conducting business and delivering mandates. A useful tool is in the United Nations Innovation Network;[425]
- Dialogue: ESCWA is a regional convener for most relevant stakeholders, to ensure that new technologies are regionally adequate and anchored in the values of the United Nations Charter and the Universal Declaration of Human Rights. This can be done by forming standing expert panels, which can then formulate position

statements on different disruptive technologies (ethics, Internet governance, cybersecurity);
- Inclusion: ESCWA and similar institutions must work to empower women and young people to be part of this technological revolution by promoting inclusive policies and purposeful template regulations;
- Capacity-building and advisory role: Regional organizations like ESCWA will support capacity-building at the highest levels of Arab Governments, and play an advisory role for national initiatives and projects;
- Bridge: ESCWA will contribute to joint regional and international expert panels addressing the risks and opportunities of 4IR technologies. Recent examples are the World Government Summit, held in the United Arab Emirates,[426] the Sustainable Digital Ecosystem Summit held in Lebanon,[427] and IDC CIO Summit held in Egypt.[428]

In summary, organizations like ESCWA that work on promoting values set out in their mandates must give the acceleration of technological development purposeful direction to ensnure dignified living for all humanity.

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