DIGITAL INDUSTRIALIZATION: ENTREPRENEURIAL FEATURES OF ADVANCED NATIONS' INNOVATION POLICIES DURING INDUSTRIAL REVOLUTION 4.0

Naumova Ekaterina Vladimirovna, Moscow State University
Nurul Mohammad Zayed, Daffodil International University

ABSTRACT

Innovation-led productivity is the main source for future growth. The rise of new digital industrial technology is known as Industry 4.0. Industrial companies from all sectors across the globe are getting down to business with Industry 4.0. Over 30 countries have introduced the digital initiatives and the investments are constantly rising. Leading countries benefit from the changing nature of production and are well positioned to increase their share in the future. Industry 4.0 will increase manufacturing productivity, shift economics, foster industrial growth, and modify the profile of the workforce. These trends will imply the rising demand for skills. Education, training and active labor market policies have a crucial role to play in this area. Comparative global positions of the USA, Germany, Japan and Singapore in terms of digital readiness are presented on the backdrop of the fourth industrial revolution. The national programs of industrial digital transformation are analyzed and common features and instruments are revealed. The need for public dialogue and special training programs is underlined. The tendency for greater horizontal and vertical collaboration along the value chains due to digitalization is stressed.

Key words: Industry 4.0, The Fourth Industrial Revolution, Productivity, Industrial Companies, Digitalization, USA, Germany, Japan, Singapore.

INTRODUCTION

Digital Technologies and Economic Growth

At the turn of the 21st century, a new technological cycle began to grow according to (Ivanova, 2002; Komarov, 2012; Freeman & Soete, 1999) the microelectronics and computer network cycle. The fourth Industrial Revolution has already started, as can be seen from the rapidly evolving digital technologies. The core evaluation criterion for innovation technologies is their role in economic development. In macroeconomics, the cornerstone of socio-economic analysis is the growth and dynamics of GDP, because economic growth also helps to improve other indexes, particularly the standard of living and quality of life (Stiglitz et al., 2009). The scientific community is largely convinced that innovation is a vital growth driver, especially from the long-term perspective. However, the relations between innovation and growth are very complex and non-linear. The role of innovation in economic growth is traditionally estimated by production, i.e. labor and capital investment (material and non-material assets) and combined factor productivity (CFP). There are three groups of factors, which can help evaluate

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.

innovations' role in economic growth: (The Innovation Imperative: Contributing to Productivity, Growth and Well-Being, 2015).

1. Investment in non-material assets, such as research effort, software, data, engineering, expertise and skills, organizational assets. OECD countries are showing a continuous increase in these investments, although they differ greatly in the size of investment and pace of investment growth. For example, the USA, Germany and Japan invest substantially in the Knowledge-based capital (KBC). In the USA, the share of KBC in material capital grew from 95.42% in 1995 to 157.71% in 2009; in Germany it grew from 54.62% to 79.63% respectively. This capital's structure is centered around software, intellectual property, different types of economic competence, in the following way (GDP percentages): 1.73; 4.16; 5.28 (the USA); 0.78; 2.91; 3.10 (Germany); 2.23; 6.07; 2.81 (Japan, 2005) (The Future of Productivity, 2015).
2. Investment in the growing CFP, as long as the growth results from a more effective use of labor and capital thanks to innovations, both social and organizational, the spillover effect produced by investment in technologies and knowledge-based capital, including global investment. Meanwhile, according to Bergeaud et. al., (2017) who researched CFP in advanced countries – the USA, European countries, Japan and Great Britain, the spread of ICT continuing over the last decades has had a much less pronounced effect on CFP than the incorporation of electricity in earlier years. Not unlikely, the technological impact will trigger another CFP wave and open up new horizons in the coming years.

As OECD predicts, most countries will continue to deal with an economic slowdown up until 2060. Apart from the aging of the population, this can be due to a labor force decline. Economic growth should be fueled by new job positions, but the resource appears to be limited, because most nations strive to stimulate high production spheres and take advantage of the digital transformation of economy (Global Digital Operations, 2018). The authors of the "Digital Dividend" believe that digitization and use of appropriate technologies can substantially improve production. For instance, an increase in the use of broadband Internet connection (cloud computing) by 10 percentage points on an industrial scale will boost an average-size company's CFP by 1.4% (0.9%) after a year and by 3.9% (2.3%) after three years. The results of the use of new technologies (as well as appropriate investment in the human and organizational capital) are complemented by spillover effects - increasingly flexible relations within the sphere, and by pushing competitors to improve performance (Sorbe et al., 2019).

LITERATURE REVIEW

Industry 4.0

Unlike Industry 3.0, which automates specific devices and processes, Industry 4.0 embraces the entire production process with full and complete digitization and data integration throughout the value-adding chain while offering products and services, material and virtual assets, ensuring transformation and integration of all operations and internal processes, building partnerships and optimizing customer services' work (Global Digital Operations, 2018). Nowadays, companies of all spheres are switching to the Industry 4.0 standard. In 2016, about one third of all firms around the world (33%) deemed their digitization levels as high, and according to a PricewaterhouseCoopers' (PwC) analytical report, it should embrace two thirds of businesses (72%) during the following five years. Manufacturers tend to choose vertical digitization across their value-adding chains, and horizontal digitization with their partners – across supply chains. Also, they improve their products' quality and functionality through the use of innovative digital services (Guellec & Paunov, 2018). As of 2016, companies planned to

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.

invest 5% of their annual income (approx. $907 billion) in digitization, mainly in sensors, interconnect devices and industrial software tools. Besides, they should invest in training and professional improvement. It is expected that 55% of the investment will pay off during two years (Industry 4.0: Building the digital enterprise, 2019). In 2018, the World Economic Forum in cooperation with A. T. Kearney released an insight report on nations' readiness for innovative production (Readiness for the Future of Production Report 2018, 2018). The forum stressed that the new production mode should:

1. Solve problems that seem insoluble today;
2. Open new horizons for man's creative potential and productivity;
3. Be maximally eco-friendly, energy- and resource-efficient;
4. Be inclusive and ensure that different countries, regardless of stage of development, as well as companies and employees, benefit from the technologies provided by the Fourth Industrial Revolution.

The review evaluates the positions of nations' – global economy players', and their ability to adjust the changes produced by the Fourth Industrial Revolution for the benefit of the society. The indicator of readiness comprises two integral indexes. One characterizes the *current structure* of a manufacturing process and depends on its scale and complexity. The second one comprises six drivers of production that are: technology/innovation, human capital, global trade/investment, the institutional framework, stable resources, and demand. Two of the values - Structure of Production and Drivers of Production (horizontal and vertical axis respectively), which are parts of the indicator, determine the "coordinates" of a country's Readiness for the Future of Production. A country falls within one of the four *archetypes* (presented from left to right and downward): *High Potential* – those with a strong current base (with limited production capabilities yet poor drivers of production); *Leading* – also with a strong current base those relying on available production facilities (with big production capabilities and effective drivers of production); *Nascent and Legacy* – with a limited and strong current base (with limited production capabilities and poor drivers of production). According to the report, the leader group is comprised of 25 countries, including the USA, Germany, Japan, and Singapore. Russia is in the group of ten nations relying on an existing industrial potential; seven nations boast high potentials, and 58 nations' potentials are going through the stage of formation (Industrial Digitalization: National Strategies and Ranking, 2019).

Table 1
NATIONS' POSITION WITHIN THE FUTURE OF PRODUCTION MATRIX

Nation	Structure of production		Drivers of production	
	value (max 10)	range	value (max 10)	range
USA	7.78	7	8.16	1
Germany	8.68	3	7.56	6
Japan	8.99	1	6.82	16
Singapore	7.28	11	7.96	2
Reference: Russia	5.71	35	5.30	43

Source: *Readiness for the Future of Production Report 2018, 2018*

According to the Information Technology and Innovation Foundation (ITIF, the USA), more than 30 countries are running projects that are similar to Industry 4.0 of Germany, and investments increase all the time. In 2010, when Industry 4.0 was incorporated, it received an

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.

estimated investment of $550 million; a same-name program in Austria incorporated that same year, received an investment of $280 million. In 2011, the Manufacturing USA project received $700,000; in 2013, the Factories of the Future program, the European Union, attracted $1,120,000,000; the Japanese Revitalization / Robot Strategy program received $916,000,000. Since 2015, other similar programs have attracted more than $1 billion: Industrie de future of France has received $1.8 billion (2015), Manufacturing Innovation 3.0 of Korea - $1.16 billion (2015), Productivity 4.0 of Singapore - $1 billion (2015), Research, Innovation and Enterprise of Taiwan - $2.3 billion (2016), Made in China - $3 billion (2017) (Ezell, 2018*)*. In 2019, BloombergNEF came up with a ranking revealing the industrial digitization status of 40 countries. Germany topped the ranking, Singapore came second, Japan – fourth. According to the BloombergNEF report, 20 out of the 40 nations were holding on to the policy of industrial digitalization; 27 nations, including Germany, Japan and Singapore, were running artificial intelligence programs. It should be noted that the USA has no integrated digitization strategy. In part, that, as well as and lack of governmental support, are reasons why the USA ranks ninth in BloombergNEF's digital industry ranking (Industrial Digitalization: National Strategies and Ranking, 2019).

National Manufacturing Digitalization Strategies

Germany has pioneered in national manufacturing digitalization. Manufacturing is the basis of the nation's economy, as Germany is the world's largest machinery and equipment exporter, so the program directs effort and resources in the country's strongest points, such as motor industry, and the nation must increase and strengthen the leadership. The current High-Tech Strategy 2025, which is Germany's document reflecting its program of innovative development, places a specific emphasis on digital development. It stresses that Germany should not only retain its technological advantages, but also be a leader and set technological trends. The federal government focuses on advanced technologies, particularly digital ones: microelectronics, communication technologies, artificial intelligence, data science, cybersecurity, Blockchain, quantum technologies. Digitization programs are supplemented with plans of practical implementation of these strategies, as well as the Roadmap Reallabore, or Work 4.0, which follows Industry 4.0. It focuses on stimulation of digital innovations and flexible innovation-oriented adjustment of employment, providing worthwhile jobs during the digitalization period.

Singapore's program replicates Germany's and focuses on manufacture too. Industrial transformation programs are aimed at restructuring of 23 spheres in keeping with the Fourth Industrial Revolution standards. Transformation maps are centered on four priorities – innovation, performance, new labor concept/skill improvement, and internationalization. To implement the program, effort is being taken to ensure cooperation and coordination between the ministries and public-private partnership. Singapore boasts an extremely dynamic strategy with an emphasis on interactive implementation. The development of Singaporean enterprises is managed by the Research and Enterprise Division (RED) of the Ministry of Trade and Industry. Its job is creating an appropriate environment for enterprises' growth and development and elimination of barriers, particularly management of taxation, funding and electronic private-public partnership services. Based on SMEs' needs, the regulatory environment has been modified, business opening, taxation and social transfer procedures have been simplified, as now

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.

they are carried out via online services. The program is run by the Infocomm media Development Authority (IMDA). It cooperates with flagship enterprises of various spheres on digitalization plans and shares with SMEs step-by-step digitalization guidelines at every stage of their development. Such instruments are already used in retail trading and logistics, and new methods are being developed for wholesale trading, food-, security services, etc. The Go Digital program offers SMEs ready-made digital packages (there are more than a hundred ones available today), electronic commerce consulting centers and the SME Digital Tech Hub. Since 2016, more than $10 billion have been invested in different spheres from software development to semiconductor production. High-tech whales, such as Google and Facebook have invested more than $10 billion of venture capital in Singaporean startup projects over the period.

In the USA, the Advanced Manufacturing Partnership (AMP) program was launched in 2011. It was aimed at strengthening the nation's competitive advantages by organizing advanced national manufacturing projects and creating jobs, which was to be achieved through the unification of industrial enterprises, universities and the Federal Government. The program pursued three goals: supporting innovations, attracting talented personnel, and creating a business-oriented environment. This resulted in the establishment in 2012 of the Manufacturing Innovation Institute (MII) operating on the public-private basis. Since 2014, the National Network for Manufacturing Innovation (NNMI) has been built around the MII. They support local startup projects and small enterprises, help scale new technologies and speed up the development of new skills.

METHODOLOGY

Today's innovation policy is undergoing significant changes. Modern innovation strategies set *complex goals:* the development of science and advanced technologies should maintain not only competition, but also help to solve social issues. The use of industry-based approaches and setting research priorities (digital technologies, new sources of energy, health care innovations, new manufacturing methods, etc.) is still the cornerstone of the innovation policy, although it is increasingly mission-oriented and is aimed not just at further growth, but at stable inclusive growth on the backdrop of major global challenges like climate change, digital revolution, population ageing. Research shows that 91% of OECD countries do use strategies of solving social issues, and 76% of these strategies pursue economic stability (Paunov & Borowiecki, 2018). For example, the High-Tech Strategy 2025 of Germany is aimed not only at making Germany a European research center and boosting the nation's competitiveness, but also at solving social issues. However, its budget is still sectorial, not mission-oriented. Japan is running the interdepartmental Strategic Innovation Program (SIP), which complements its scientific and technological strategy (The 5 Science and technology basic Plan), is focusing on the nation's economic growth and strengthening its position of a global industrial hub. The SIP uses a pragmatic approach, which relies on a balance between social problems and short-term private sector's objectives. For example, one of the goals pursued by SIP Stage 1 is the "innovative internal combustion technology," which was manufacture-oriented, yet it has helped reduce greenhouse gas releases. The USA's new integrated industrial program is complemented by a number of initiatives, such as the Sustainable Manufacturing Clearinghouse incorporated by the Department of Commerce. It is a kind of knowledge gateway, which highlights programs and resources contributing to the development of eco-friendly industries. To accomplish the goals set

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.

by strategic programs, it is often necessary to use specific mechanisms, which contribute to breakthrough innovations. They produce radical changes as new products and services are introduces, have a tremendous potential for growth and make existing technologies obsolete (Egli et al., 2015).

RESULTS & DISCUSSION

New Features of the Innovation Policy

The Fourth Industrial Revolution has gained a tremendous pace, and the use of its effects for economic growth is the center-point of the innovation policy, which also integrates the social and environmental segments. Advanced technologies have the potential to significantly increase manufacture. For instance, digital technologies help reduce expenditures, contribute to cooperation and innovations' availability, eliminate the borders between industrial and service innovations and speed up the innovation cycle. However, they threaten to rob many citizens of their jobs, both executives and managers. Consequently, governments switch priorities and focus on man and creation of a kind of society, which should use the technological potential to improve the quality of life and achieve social closeness. This is what the Strategy for American Innovation, Industry 4.0 (Germany), Society 5.0 (Japan), and the Smart Nation (Singapore) are focusing on. The leading nations, particularly Germany and Japan, broadly rely on public-private partnership. The new approaches enable the governments to quickly and effectively build partnership relations between manufacturers, science and the society and open up new horizons. Rapidly changing technologies create a risk of persistent support of outdated technologies and related ineffective innovations; therefore, it is necessary to not just rely on governmental initiatives, but also on innovators themselves. DARPA (the United States) is an example of how a flexible and autonomous approach can help find required practical solutions. It places an emphasis on achieving the end result rather than on the type of technologies used to achieve it. In the USA, DARPA has pioneered in endowing innovators with financial gifts: the agency announced the DARPA Grand Challenge (2004) of $1,000,000, which was a driverless car competition in a desert environment. Although no one won the prize, a decade later, most car makers were working on driverless vehicles. Since the time, the agency has announced prizes for building human-like robots, etc. Flexibility, quick response, and elimination of bureaucratic hurdles are vital for innovators and are widely incorporated by innovation policies. For example, Agentur zur Förderung von Sprunginnovationen, a German agency was launched in late 2019 by the Federal Ministry of Education and Research, Ministry for Economic Affairs and Energy, with the goal of promoting breakthrough inventions. It relies on the DARPA model (Paic & Viros, 2019). The agency should become a practical governmental support tool for breakthrough innovative concepts and their immediate entrance to the market. Industry concept competition is the agency's working tool. Digital and infrastructural development (for example, creation of data exchange platforms, supercomputers for artificial intelligence) is crucial for scientific research. Japan is running the High Performance Computing Infrastructure (HPCI) program. The objective is to build a powerful computerized infrastructure for universities and research centers focusing on a variety of spheres. The annual budget is more than $120,000,000 (Innovation Policies in the Digital Age / OECD Science, 2018).

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.

New types of Manufacturing and Knowledge

Digital transformation will dramatically change the global economy and its competitive environment. According to the PwC review, most manufacturers expect tremendous output from digitalization (Industry 4.0: Building the digital enterprise, 2019). When the transition is over, successful businesses should become true digital enterprises capable of producing material goods supplemented with digital interfaces and innovative services, which rely on big data. These digital enterprises are going to integrate and cooperate with customers and suppliers within digital industrial ecosystems. More than 80% of businesses expect that big data analysis will serve as a basis for further development of the business segment, and the biggest obstacle is lack of digital culture within companies themselves rather than technologies. So far, only a few employees per company have sufficient expertise, and less than 50% of companies mentioned in the PwC review have qualified big data processing staffs. Digitalization poses the need for qualified staffs. Lack of trained personnel weakens the effect of using digital technologies. Supposedly, a 100% effect observed in highly productive companies means a 68.56% effect observed in those showing lower performance (for branches, the ratio is 100% and 90.87% respectively) (Sorbe et al., 2019). In the years to come, companies are going to have to come up with complex digital solutions, a digital environments for vertical interaction across the value-adding chain from product development and purchase through production and logistics, as well as horizontal interaction across the value-adding chain with interaction with partners, suppliers and customers. Essentially, this will require new skills and competencies. In 2017, the European Committee carried out a poll, during which 37% respondents agreed that robots and artificial intelligence would eliminate more jobs than they could provide; 37% agree rather than disagree 16% disagree rather than agree, and 4% absolutely disagree to the statement, and 6% were undecided (Innovation Policies in the Digital Age / OECD Science, 2018). Therefore, the advent of new technologies raises serious public concern. To meet these social challenges successfully, it is necessary to ensure interaction, openness and involvement of the public in the problem-solving process. It is important to prepare the public for the transition to increase the number of qualified employees and their potential, but this is not about personnel training alone. Governmental authorities executing an innovative policy should interact and cooperate with those responsible for education and labor market, keep them informed about new industrial qualification criteria to ensure improvement of skills required by digital innovations. For example, innovations in the motor industry are increasingly demanding in terms of software development and expertise in artificial intelligence, as they complement traditional background knowledge in mechanics and electronics.

CONCLUSION

Today, all countries aiming for manufacturing digitalization maintain training and re-training programs. For example, the Singaporean government has launched a series of educational and training programs for employees and graduates to improve their skills, and it has funded training classes that focus on advanced technologies. Reeducation and skill acquisition are stimulated by educational allowances and grants. Japan's educational system is being remodeled for employees to be prepared for working in the economy of future. Programming has

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.

become a compulsory primary school subject, and high schools are increasingly interested in teaching mathematics and information technologies. Germany is taking steps to stimulate the learning of mathematics, informatics, natural science and technology (MINT), increase the number of scientific workers and post-graduate students, and support professional and supplementary education. The USA outlines its higher education policy in such a way as to increase the number of technical experts, and it increases grants in the sphere of Scientific Technical Engineering and Mathematics (STEM) and the funding of mathematics and technical engineering education. With the growing digital technologies, the world is entering an era of extensive network interactions. Companies come up with new types of products and services featuring digital functions, which embrace a product's lifecycle and therefore provide for a closer contact with end users. Also, they invest money in digital services and generate integrated solutions for the existing customer ecosystem, often in cooperation with value-adding chain partners. The authors of the PwC review believe that in five years different regions will achieve a similar degree of integration. Instead of separating regions, Industry 4.0 is going to strengthen ties between companies and nations.

REFERENCES

Bergeaud, A., Cette, G., & Lecat, R. (2017). Total factor productivity in advanced countries: A long-term perspective. *International Productivity Monitor*, (32), 6.

Egli, F., Johnstone, N., & Menon, C. (2015). Identifying and inducing breakthrough inventions: An application related to climate change mitigation.

Ezell, S. (2018). Why Manufacturing Digitalization Matters and how Countries are supporting it. *Information Technology & Innovation Foundation, 66*.

Freeman, C. & Soete, L. (1999). The Economics of Industrial Innovation. Cambridge (MA): MIT Press.

Global Digital Operations. (2018). PwC Survey.

Guellec, D., & Paunov, C. (2018). Innovation Policies in the Digital Age.

Industrial Digitalization: National Strategies and Ranking. (2019). Bloomberg NEF.

Industry 4.0: Building the digital enterprise. (2019). PwC 2016 Global Industry 4.0 Survey.

Ivanova, N.I. (2002). Sphere of Innovations/Global Economy: Global Tendencies Over the Past 100 Years, Korolyov I.S. M, Yurist, 210.

Komarov, V.M. (2012). The basics of innovation theory /institute of economic policy named after gaidar E.T.M, Delo Publishing House, 190.

OECD. (2015). The future of productivity. *Joint Economics Department and the Directorate for Science, Technology and Innovation Policy Note.*

Organisation for Economic Co-operation and Development. (2015). *The Innovation Imperative: contributing to productivity, growth and well-being. OECD Publishing.*

Paic, A., & Viros, C. (2019). Governance of science and technology policies.

Paunov, C., & Borowiecki, M. (2018). The governance of public research policy across OECD Countries.

Readiness for the Future of Production Report 2018. (2018). World economic forum insight report in collaboration with A.T. Kearney.

Sorbe, S., Gal, P., Nicoletti, G., & Timiliotis, C. (2019). Digital Dividend: Policies to Harness the Productivity Potential of Digital Technologies.

Stiglitz, J., Sen, A., & Fitoussi, J.P. (2009). *The Measurement of Economic Performance and Social Progress Revisited:Rreflections and Overview* (No. 2009-33). Sciences Po.

Citation Information: Vladimirovna, N.E., & Zayed, N.M. (2021). Digital industrialization: entrepreneurial features of advanced nations' innovation policies during industrial revolution 4.0. *Academy of Entrepreneurship Journal, 27*(6), 1-8.