BUILDING INDUSTRY 4.0 CAPACITY

Need Analysis of Six APO Economies

The Asian Productivity Organization (APO) is an intergovernmental organization committed to improving productivity in the Asia-Pacific region. Established in 1961, the APO contributes to the sustainable socioeconomic development of the region through policy advisory services, acting as a think tank, and undertaking smart initiatives in the industry, agriculture, service, and public sectors. The APO is shaping the future of the region by assisting member economies in formulating national strategies for enhanced productivity and through a range of institutional capacity-building efforts, including research and centers of excellence in member countries.

APO members
Bangladesh, Cambodia, Republic of China, Fiji, Hong Kong, India, Indonesia, Islamic Republic of Iran, Japan, Republic of Korea, Lao PDR, Malaysia, Mongolia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Turkey, and Vietnam.

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FOREWORD

The world is undergoing a rapidly evolving technological revolution that is fundamentally transforming production systems. In the APO region, the major challenge in coping with this new generation of technologies and the rise of the Fourth Industrial Revolution (Industry 4.0) is the need for qualified human resources to plan, oversee, and operate digital processes and services. Research on Capacity Development Needs for Industry 4.0 was initiated by the APO to provide comprehensive recommendations to all actors in the economy to address the critical requirements for human capital readiness to adopt Industry 4.0.

Analysis shows that all countries included in this research in the clusters of nascent economies, legacy economies, and leading economies show strength in their economic development dynamism and future-oriented governance structures and policies. Their main needs are currently similar. All share weaknesses in science, R&D, and digital infrastructure. Therefore, the recommendations focus on how governments, businesses, and related institutions could address R&D, innovation, industrial policies, education, and labor market policies. The reform of higher and vocational education to introduce more effective, efficient learning methods like a problem-based curriculum in a digital-learning environment, closer links between industry and educational institutions, continued learning throughout the work life cycle, and organizing policy learning on an international or intergovernmental scale was emphasized in the research recommendations.

Insights from this publication will be useful inputs for policymakers in government and public agencies as well as the business sector in efforts to guide the industrial transformation process in APO members. The valuable contributions and commitment of all the experts who participated in this research project are very much appreciated by the APO.

Dr. AKP Mochtan
Secretary-General

EXECUTIVE SUMMARY

This report covers Indonesia, Vietnam, India, the Philippines, Republic of China (ROC), and Malaysia. With some limitations regarding the ROC, for which data were missing and needed to be estimated, a common database was employed, which makes extensive use of statistical indicators collected and provided by the World Economic Forum. According to those indicators, the six countries can be grouped into three pairs:

1. Nascent Economies: Indonesia and Vietnam, with a limited current economic base and unfavorable drivers of production, which puts them at risk for the future.

2. Legacy Economies: India and the Philippines, with a strong current economic base but also unfavorable drivers of production, which also puts them at risk for the future.

3. Leading Economies: the ROC and Malaysia, with a strong current economic base and favorable drivers of production, which puts them in a good position for the future.

Deeper analysis revealed that all countries show strengths regarding their economic development, dynamism, and future-oriented governance and policies. On the other hand, all countries share weaknesses with respect to science, R&D, and digital infrastructure.

The leading economies (ROC, Malaysia) tend to score somewhat better in the educational domain than the nascent (Indonesia, Vietnam) and legacy (India, the Philippines) economies.

In terms of innovation capabilities, the nascent and legacy economies score less well in human capital (knowledge and competence of employees) and complexity capital (the ability to combine diverse knowledge bases to produce complex products). Conversely, they have strengths in relational capital, i.e., the sharing of knowledge and ideas with external partners like other companies and educational or research institutions. The leading economies, in contrast, score well in human and complexity capital and relatively lower in relational capital.

All countries show reasonably good scores regarding structural capital, defined as the sharing of knowledge and ideas within a company. All countries have set up consistent, comprehensive political strategies, programs, and initiatives.

The critical needs are rather similar across the countries, including:

- Increased investment in digital infrastructure, with a special emphasis on cybersecurity, networking, cloud computing, data analytics, the Internet of Things (IoT), and other technologies relevant for Industry 4.0.

- Increased budgets and policy support for R&D, with a focus on cooperative R&D among companies and between industry and academia.

- New, more effective and efficient learning methods as well as new technological subjects (AI, data analysis, robotics) in educational programs.

- Better links and matches between vocational education and industries.

- Stronger, more intensive technology transfer between foreign and national enterprises as well as among national enterprises.

Recommendations were made for governments and social partners in the areas of R&D, innovation, and industrial policies on the one hand, and educational and labor market policies on the other. The recommendations on R&D, innovation, and industrial policies for governments include:

- In all countries, investment in stationary and mobile ICT infrastructure is needed. In the nascent and legacy economies, the focus might be more on broad coverage of all, especially rural regions. In leading economies, the step forward to 5G networks needs serious planning as a prerequisite for many Industry 4.0 applications.

- All countries need some form of stimulation for R&D. As a general incentive for industry to engage in more R&D, tax reduction programs may be useful. For more specific issues, dedicated funding programs will be more effective and efficient.

- For the systematic fostering of cooperative R&D among companies or between companies and academia, funding programs might be a more targeted approach.

- Regarding knowledge domains, R&D support should reflect the structural conditions and needs of the individual countries. In leading economies like the ROC, these can be very specific domains of advanced engineering and ICT. In nascent or legacy economies, like India or the Philippines, ICT applications in agriculture may serve their development needs very well.

- An issue of importance for all countries is cybersecurity, another prerequisite for Industry 4.0. Cybersecurity should be addressed in R&D as well as educational policies. Furthermore, international activities, e.g., moderated by the APO, might help to establish common standards.

- In more general terms, international policy learning in R&D, innovation, education, and labor market policies with respect to preparedness for Industry 4.0 could be a very helpful activity of international and intergovernmental organizations like the APO.

The recommendations on educational and labor market policies for governments are:

- Reform higher and vocational education, including the introduction of more effective, efficient learning methods like project-based or problem-based learning and digital-learning environments.

- Provide closer links between education and industry and other employers.

- Internationalize education and cooperate with international providers of education.

- Give more attention to continuing learning along the work life cycle, as provided by vocational and higher education institutions. The latter will be mostly responsible for educational subjects close to research, which involves many issues in the Industry 4.0 context.

- In the areas of educational and labor market policies, organizations like the APO might make extremely valuable contributions by organizing policy learning on an international or intergovernmental scale. The APO's existing Centers of Excellence could serve as hubs for educational activities.

Recommendations on R&D, innovation, and industrial policies addressed to social partners are:

- Industrial and employers' organizations can arrange dialogues among their members to disseminate knowledge and experience related to advanced technologies. They can also collect and structure their members' demands and suggestions regarding public R&D and innovation policies and communicate those suggestions to the government.

- Trade unions can inform their members of coming changes and advise them on further education and training they might need to stay in the labor market. They can also communicate their members' needs to governments so that employees' voices can be heard and measures for socially just, fair innovation can be taken.

- On an international or intergovernmental scale, organizations like the APO can invite governments and sectoral social partner organizations to discuss and develop policies and standards tuned to the needs of specific sectors.

Finally, the recommendations on educational and labor market policies to be addressed by social partners are:

- Social partners may use their own educational institutions to inform and educate their members with respect to upcoming changes or they may set up new education programs to do so.

- Most importantly, social partner organizations can help the government and other public agencies in the education sector to align educational programs closer to the requirements of the world of work. They can help to set up or fine-tune curricula and provide professional standards to guide curriculum development.

METHODOLOGY

Sources and Authorship

This report is the result of a common endeavor by six national experts, an APO Secretariat program officer, and a chief expert, as listed below.

All sections in this report which refer to specific countries are based predominantly on the work of the national experts. While some reformulation and shortening were necessary, the chief expert attempted to preserve the messages, perspectives, and outlooks of the national experts' analyses and views.

All sections not referring to individual countries were drafted by the chief expert, taking into account the results of the six national studies and comments and suggestions of the national experts and APO program officer.

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Methodology Overview

To assess the capacity developments needs for Industry 4.0 in the ROC, India, Indonesia, Malaysia, the Philippines, and Vietnam, two perspectives were used to design the methodology. The first perspective views the six economies in the broad context of all elements in their national innovation systems:

- Economy (divided into global economic factors with emphasis on manufacturing and economic factors specific to Industry 4.0)

- R&D

- Education (divided into global educational factors and economic factors specific to Industry 4.0)

- Labor market

- Digital infrastructure (treated as a separate factor because of its importance for Industry 4.0)

- Policies (relevant to innovation in general and ICT/Industry 4.0 specifically)

The second perspective examines their innovation capabilities:

- **Human capital:** The knowledge of people working in the nation's industry

- **Complexity capital:** The combination of specialized knowledge bases needed to produce complex products

- **Structural capital:** The ability of companies to bring internal knowledge bases together

- **Relational capital:** The ability of companies to combine internal and external (other companies, research institutions) knowledge bases

In this way, more general socioeconomic prerequisites for the successful adoption of Industry 4.0 are combined with a specific focus on the capabilities of the countries to successfully implement Industry 4.0 on a company level. The two perspectives overlap in some elements, e.g., indicators describing the education system on the one hand and human capital on the other are to a certain extent identical.

In this integrated report, results of data analysis referring to the data above are combined and contrasted with the quantitative and qualitative results of the individual country reports. Specifically, the qualitative assessments of the national experts are vital for the triangulation of the general quantitative data.

Characterization of the Six Economies

It should be noted that most data used in this report are taken from the World Economic Forum's Readiness for the Future of Production Report (FoP) (http://www3.weforum.org/docs /FOP_ Readiness_Report_2018.pdf). To understand the relative strengths and weaknesses of the six countries in detail, it is helpful to consider first their general economic and societal positions. Figure 1 shows these countries in terms of economic complexity, based on the Economic Complexity Index (ECI) calculated and published by the Growth Lab at Harvard University (http://atlas.cid.harvard.edu/). Economic complexity can be understood as the level of knowledge intensity of products manufactured. The ECI is calculated by considering products exported from a country. Complex products can only be made (and exported) by a few other countries, while less complex products can be manufactured (and exported) by many others. The ECI score of a country depends on the composition of the products it exports and the complexity value of those products.

Economic complexity can be used as a first rough estimate of the sophistication of a nation's economy, which can be regarded as a prerequisite for the ability to take up cutting-edge technologies like those associated with Industry 4.0. The scores are normalized so that they can be interpreted as percentages of the best score (i.e., Japan's).

Two countries, Indonesia and Vietnam, had an ECI score of less than half of the highest score. Four economies, the ROC, India, Malaysia, and the Philippines, had scores of more than half of the highest score. Thus, those four countries produce rather complex products, and the other two specialize in less complex products.

Figure 2 combines the ECI scores with the Human Development index (HDI) as a more general prosperity measure and with the classification in the World Economic Forum's Readiness for the FoP Report as nascent, legacy, high-potential, and leading. The latter classification is derived from the FoP's Readiness Diagnostic Model Framework. It distinguishes two main groups of socioeconomic factors:

- The structure of production, with the two factors of complexity described above and scale, i.e., the size of the national economy, in terms of GDP.

- The drivers of production, i.e., technology and innovation, human capital, global trade and investment, institutional framework, sustainable resources, and demand environment.

FIGURE 1

ECONOMIC COMPLEXITY INDEX (ECI) SCORES OF THE SIX ECONOMIES. NORMALIZED VALUES ARE SHOWN, WITH THE HIGHEST SCORE SET EQUAL TO ONE AND THE LOWEST SCORE SET EQUAL TO ZERO. THE ECI SCORE FOR THE ROC WAS ROUGHLY AND CONSERVATIVELY ESTIMATED BECAUSE NO DATA WERE AVAILABLE.

ECI scores

Economy	Score
Malaysia	0.69
ROC	0.78
Philippines	0.6
India	0.58
Indonesia	0.46
Vietnam	0.46

0   0.2   0.4   0.6   0.8   1
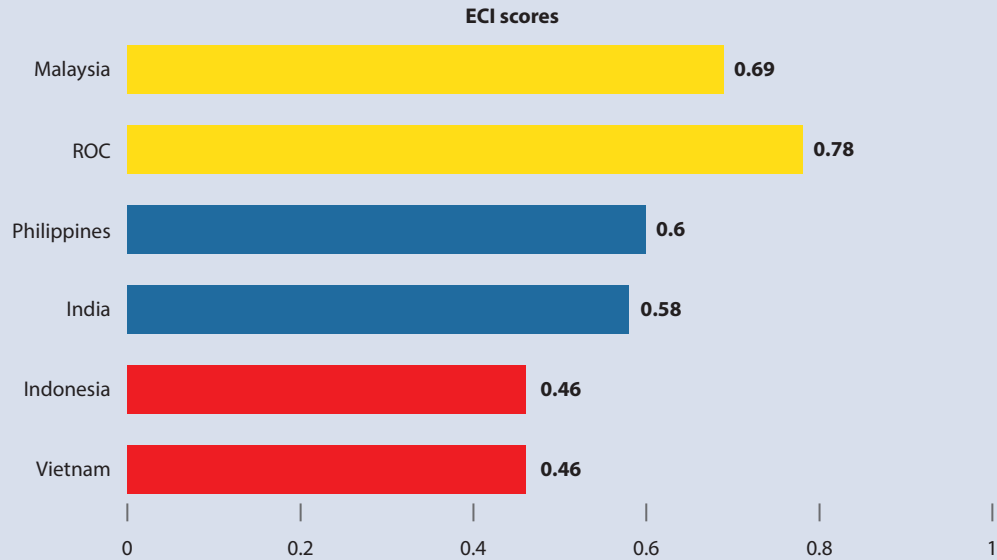
FIGURE 2

RANKINGS OF THE SIX ECONOMIES IN THE HUMAN DEVELOPMENT INDEX (HDI), ECONOMIC COMPLEXITY INDEX (ECI), AND READINESS FOR THE FUTURE OF PRODUCTION REPORT 2018. ORIGINAL, NONNORMALIZED ECI SCORES ARE SHOWN. THE ECI SCORE FOR THE ROC WAS ROUGHLY AND CONSERVATIVELY ESTIMATED BECAUSE NO DATA WERE AVAILABLE.

◆ Leading   ■ Legacy   ● Nascent
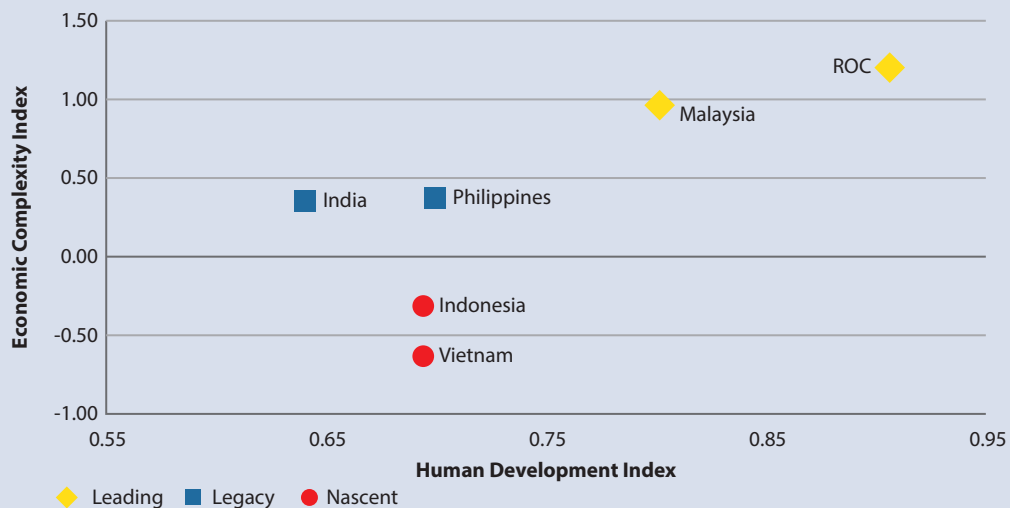
The structure of production factors describes the current baseline of an economy, and the drivers of production relate to the position of an economy to take advantage of new developments like Industry 4.0. The positions of the six countries with respect to structure and drivers of production are summarized Table 1.

TABLE 1

STRUCTURE AND DRIVERS OF PRODUCTION IN THE SIX ECONOMIES.

High-potential Economies	Leading Economies
• Small/simple structure of production: Limited current base	• Large/complex structure of production: Strong current base
• Favorable drivers of production: Positioned well for the future	• Favorable drivers of production: Positioned well for the future
○ No countries in sample	○ ROC ○ Malaysia
Nascent Economies	**Legacy Economies**
• Small/simple structure of production: Limited current base	• Large/complex structure of production: Strong current base
• Unfavorable drivers of production: At risk for the future	• Unfavorable drivers of production: At risk for the future
○ Indonesia ○ Vietnam	○ India ○ Philippines

According to this analysis, India, Indonesia, the Philippines, and Vietnam are exposed to some risk for the future because of unfavorable scores for the drivers of production. The ROC and Malaysia, on the other hand, not only show a strong current economic base but also good prospects for the future because of favorable scores for the drivers of production. As seen in Table 1, there is no high-potential economy in the current research sample. Moreover, except for Hong Kong, there are no high-potential economies among APO members.

Thus, the six countries selected represent the overall APO membership fairly well, at least at this rather approximate level of classification into the four paradigmatic economic types.

OVERVIEW OF KEY FINDINGS

All six economies show strengths in their economic development and dynamism as well as future-oriented governance and policies. On the other hand, they all share weaknesses with respect to:

- Science and R&D

- Digital infrastructure

The leading economies (ROC, Malaysia) tend to score somewhat better in the educational domain than the nascent (Indonesia, Vietnam) and legacy (India, Philippines) economies.

Regarding innovation capabilities, the nascent and legacy economies score less well in human capital (knowledge and competence of employees) and complexity capital (ability to combine diverse knowledge bases to produce complex products). Conversely, they have strengths in relational capital (sharing of knowledge and ideas with external partners like other companies and educational or research institutions). The leading economies, in contrast, score well in human and complexity capital but relatively lower in relational capital. All countries show reasonably good scores for structural capital (sharing of knowledge and ideas within the company).

The six countries have set up more or less consistent, comprehensive political strategies, programs, and initiatives. Those strategies reflect the positions and characteristics of the countries, e.g., emphasizing ICT in agriculture in India and advanced engineering and ICT in the ROC.

Taking into account the diverse characteristics of the economies, their critical needs are surprisingly similar, including:

- Increased investment in digital infrastructure, with a special emphasis on cybersecurity, networking, cloud computing, data analytics, the Internet of Things (IoT), and other technologies associated with Industry 4.0.

- Increased budgets and policy support for R&D, with a focus on cooperative R&D among companies and between industry and academia.

- New, more effective, efficient learning methods as well as new technological subjects (AI, data analysis, robotics) in educational programs.

- Better links and matches between vocational education and industries.

- Stronger, more intensive technology transfer between foreign and national enterprises as well as among national enterprises.

In the following, the detailed results for the three pairs of economies, i.e., nascent, legacy, and leading, and for the six individual countries are presented. The indicators were calculated as

described above in the Methodology section (http://www3.weforum.org/docs/FOP_Readiness_ Report_2018.pdf), and all indicators are listed in Annex A.

Key Findings for the Nascent Economies: Indonesia and Vietnam

Assessment and SWOT Analysis
Core Results of the Domains (Contextual Conditions, Innovation Capability Elements)

Figure 3 shows the contextual conditions for Indonesia and Vietnam, the two nascent economies in this study. For all indicators, Indonesia shows generally higher scores than Vietnam. The individual results are as follows:

- Both countries show reasonably good scores for the manufacturing indicators in general and for the economic indicators relevant to Industry 4.0. This shows that manufacturing is important in both countries and that ICT-based business models have gained some ground.

- The R&D indicators show a marked weakness in science and R&D for both countries.

- In the global educational indictors, and even more so in the educational indicators specific to Industry 4.0, Indonesia scores well, reflecting an appropriate level of science, technology, and mathematics (STEM) education. Vietnam lags somewhat behind.

- The labor market indicators have low scores, indicating rather low levels of knowledge-intensive employment and a lack of ability to attract and retain talent.

- Digital infrastructure indicators are low for both countries, indicating a need for further investment to catch up.

- In policy and governance, Indonesia scores particularly well. The country seems to be attentive to technological challenges and to set policy priorities accordingly, e.g., in the domain of cybersecurity. Again, Vietnam lags somewhat behind.

Figure 4 shows the scores for innovation capability in general and for the four dimensions of innovation capability in detail. Strengths with respect to Indonesia appear in the domains of structural and relational capital. Thus, the sharing of knowledge seems to work rather well within companies as well as among companies and between the economy and academia.

The complexity capital score is especially low for both countries. They do not show advanced capabilities in producing complex products. In addition, the human capital indicator scores are moderate. There seems to be room for improvement in education and lifelong learning, which is more evident in Vietnam than in Indonesia.

SWOT Analysis

Table 2 shows the strengths and weaknesses of the two countries as identified by the national experts for Indonesia and for Vietnam. These results add depth to the quantitative data while validating them.

Both countries enjoy stable, substantial economic growth. On the other hand, the levels of economic sophistication and ICT usage in industry are not very well developed. Both countries could benefit

FIGURE 3

CONTEXTUAL CONDITIONS: INDONESIA AND VIETNAM.
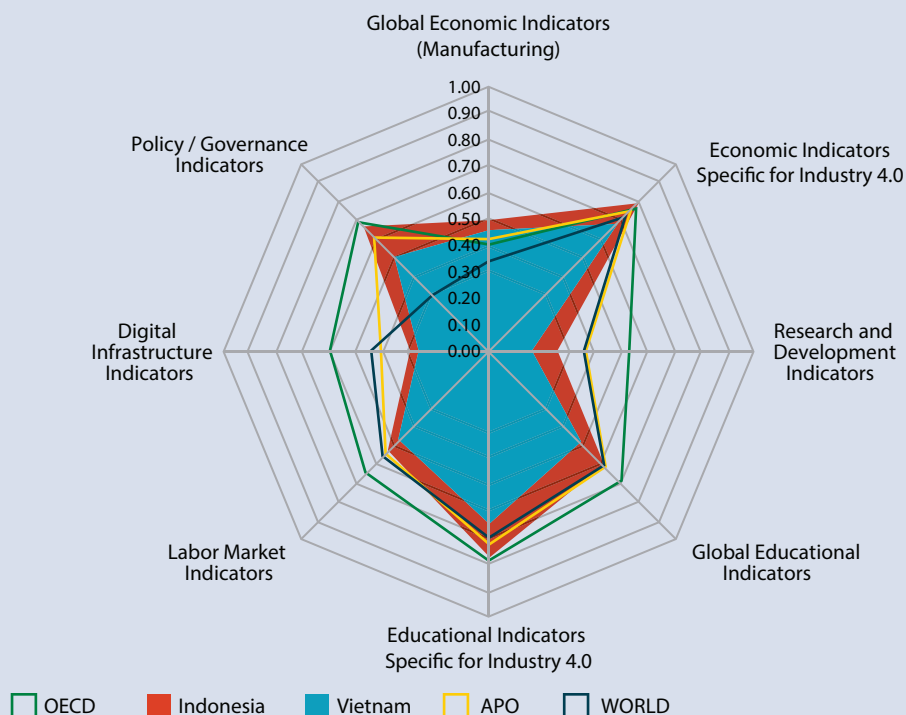
FIGURE 4

INNOVATION CAPABILITY: INDONESIA AND VIETNAM.
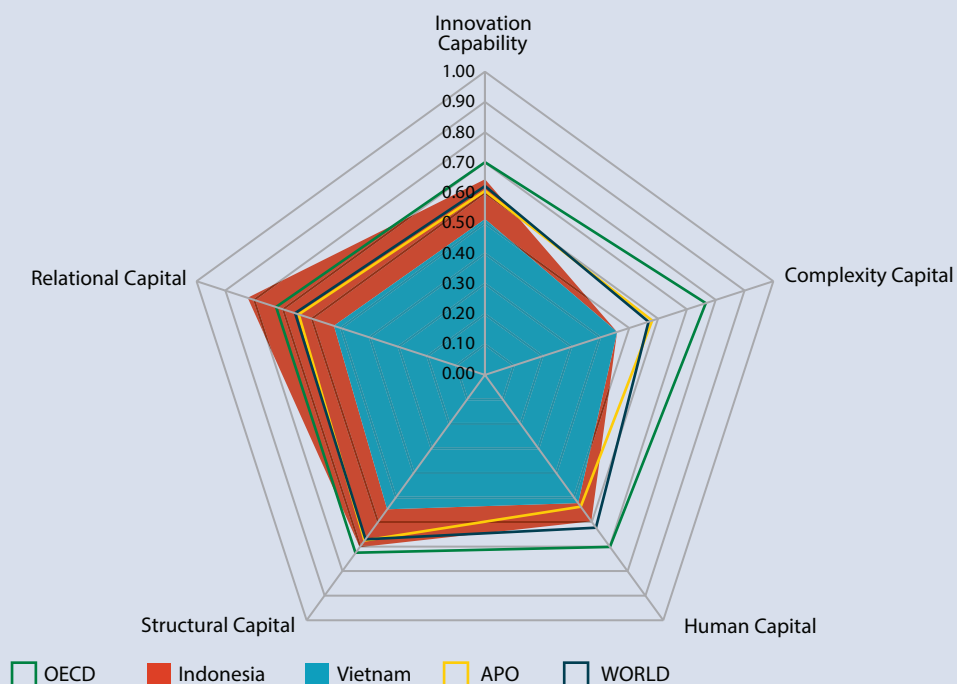
TABLE 2

SWOT ANALYSIS PART 1: INDONESIA AND VIETNAM.

Indonesia and Vietnam: Strengths and Weaknesses		
Country	**Strengths**	**Weaknesses**
Indonesia	• **Economic conditions are good with steady growth** • **Demographic bonus** High proportion of productive workforce among population compared with other countries, especially in Asia • **Active role of government in entering the Industry 4.0 era** Launch of "Making Indonesia 4.0" and its roadmap	• **Geographic landscape** Imbalance in population distribution causes obstacles in the smooth running of logistics and results in high costs • **Lack of capable human or talent resources in IT, slowing digital transformation efforts** • **Low support for digital infrastructure and Internet use, resulting in a low level of digital transactions** • **Companies (business sector) are still short-term profit oriented, tend to become rent seekers, and are risk averse**
Vietnam	• **Growing economy** High economic growth High FDI flows Low labor costs • **R&D potential in FDI firms and human resources** High technologies in FDI firms Rising number of qualifications as PhDs and professors • **Improving education system** More seeking higher qualifications (Master's degrees, PhDs) Improving opportunities for academic education Growing number of higher education institutions • **Labor force strong in quantitative terms** Labor force Low labor costs Many employees in manufacturing • **Promising digital infrastructure** High-speed Internet Many Internet subscribers High-speed 4G network • **Efforts to modernize legislation** High level of activity to adapt legislation and government to digital era	• **Less developed economic sophistication** Low productivity Low absorptive capacity Poor business models • **Low R&D potential in domestic firms, science, and research** Low technologies in domestic firms Low R&D expenditure in domestic firms Low ranking in number of scientific and technical publications Poor relationships among domestic firms for R&D • **Weaknesses, especially in practice-oriented education** Weak practical methods in vocational schools and universities Weak vocational schools Weak competence level of learners Weak competence level of skilled workers • **Labor force weak in qualitative terms** Low level of knowledge-intensive employment Low labor productivity Weak labor standards and protective laws Poor working environment Weak labor mobility between domestic economy and international labor market • **Weaknesses in Internet usage, e-government, and IT security** Low proportion of Internet users Weak e-government Poor management of network security • **Weakness in practical impact of legislation** Weak impact of legal system Some laws and policies not suitable for Industry 4.0 Weak coordination of management agencies Weak connection between laws and policies and the market

from demographic bonuses, providing a strong labor force in quantitative terms. However, the labor force is still lacking future-oriented competencies in qualitative terms in both countries. In Vietnam in particular, the education system struggles with building up practice-oriented skills.

While Table 2 shows strengths and weaknesses with a focus on the present situation, Table 3 lists opportunities and threats from a future viewpoint.

TABLE 3

SWOT ANALYSIS PART 2: INDONESIA AND VIETNAM.

Indonesia and Vietnam: Opportunities and Threats		
Country	**Opportunities**	**Threats**
Indonesia	• Absorption of more professional expert workers • Development of startups in various fields • Opportunities to increase income, quality of life, life expectancy by adopting new technologies • New technology adoption could raise efficiency in business processes to increase company profits and worker incomes	• Reduced employment due to mechanization • Marginalization or unemployment of unskilled labor force • More skilled foreign workers may replace domestic ones • Weakening of social cohesion and rising disparity may create security risks • Concerns regarding cybersecurity
Vietnam	• **Economic opportunities** Expanding exports Growing manufacturing sector New occupational opportunities in AI, data analysis, energy, logistics, nanotechnologies • **R&D potential** Transferring technologies between FDI and domestic firms Exchanging ideas and technologies Educating employees for higher levels of skills and income • **Opportunities in education** New topics associated with Industry 4.0 enrich curricula Exchanging students between Vietnam and international universities Universities internationalize and develop • **Labor market opportunities** More employment More knowledge-intensive jobs Attraction of more qualified personnel • **Opportunities in digital infrastructure** IoT applications in industries Expanding 5G network • **Opportunities for government and policies** Develop modern legislation for the digital age Develop e-government	• **Economic threats** Big income gaps among economic sectors Dependency on external, foreign capacity Replacing skilled workers with machines • **Lack of R&D potential** Dependency on FDI firms continues Transfer of low-level technologies from abroad to Vietnam • **Threats to education system** Introducing new teaching methods is difficult because many teachers still rely on traditional methods Increasing lag in number of qualified scientists and engineers • **Labor market threats** Higher unemployment through automation Foreign workers may replace domestic workers Increasing income gaps • **Threats regarding IT security** Security risks for citizens and enterprises • **Threats for government and policies** Coordination problems due to overlapping law and policy management among administrative agencies

Both national experts see opportunities in embracing new technologies and being able to modernize the economy and public administration. They also see dangers in automation, potentially making workers redundant.

Especially in Vietnam, the strong dependence on foreign companies could be an opportunity if domestic firms learn from foreign ones and technology transfer takes place. On the other hand, a continuing one-sided dependency on foreign companies, predominantly in terms of R&D capacity, is seen as a threat.

Level of Industry 4.0 Integration into National Policies: Indonesia

The Indonesian government launched a roadmap called "Making Indonesia 4.0" in April 2018. Under this plan, Indonesia will initially focus on the five main sectors of: 1) food and beverages; 2) textiles and apparel; 3) automotive; 4) chemicals; and 5) electronics. These sectors were chosen after evaluation of economic impacts and implementation feasibility criteria that included measures of GDP, trade, potential impacts on other industries, size of investment, and speed of market penetration. Specific strategies and programs for the five main sectors have also been determined by the government, as summarized below:

1. The food and beverage 4.0 strategy focuses on encouraging productivity in the upstream sector comprising agriculture, livestock, and fisheries through the application of and investment in advanced technologies such as automatic monitoring systems and autopilot drones. Indonesia will specifically help MSMEs along the value chain to adopt technologies that can increase their production output and market share. A further important point is to invest in packaged food products to capture all domestic demand in the future in line with increasing consumer demand and at the same time to increase exports by utilizing access to agricultural resources and the scale of the domestic economy.

2. In textiles and apparel, the core issues are increasing capacity in the upstream sector, focusing on the production of chemical fibers and clothing materials as well as increasing manufacturing and labor productivity through the application of technology, optimizing factory locations, and increasing skills. Furthermore, along with a shift in demand from basic to functional clothing, Indonesia must be able to build production capabilities and increase economies of scale to meet functional clothing demand that continues to grow, in both the domestic and export markets.

3. The automotive 4.0 strategy includes increasing local production of important raw materials and components through technology adoption and infrastructure development, such as the construction of integrated industrial zones and more efficient logistics platforms. More issues are cooperating with world OEM companies to increase exports, with a focus on multipurpose vehicles (MPVs), environmentally friendly, low-cost vehicles, and sport utility vehicles (SUVs), and building an ecosystem for the electric vehicle (EV) industry, starting with the ability to manufacture electric motorbikes and then electric cars based on inevitable EV adoption in the future.

4. In the chemical industry, the development of domestic petrochemical supply capacity to reduce import dependence is to be encouraged. A competitive-cost chemical industry should use oil and gas resources and optimize the location of industrial zones, including the construction of chemical production sites that are closer to the locations of natural gas extraction. In addition, it should adopt Industry 4.0 technology and accelerate R&D activities, e.g., to develop the next generation of chemical production capabilities of biofuels and bioplastics.

5. In the electronics industry, leading global players will be attracted by incentive packages. Development goals focus on value-added electronic components. The capacity of the domestic

workforce is planned to be developed through intensive training and attracting foreign workers in certain fields. Finally, superior domestic industry players will be developed which are competent to perform continued innovation and accelerate technology transfer.

Level of Industry 4.0 Integration into National Policies: Vietnam

The Vietnamese government has issued a series of decisions and initiatives referring to infrastructure, industrial applications, and human resources for Industry 4.0. They include:

- Resolutions No. 19-2017/NQ-CP dated 06/02/2017, No. 35/NQ-CP dated 16/5/2016, and No. 36a/NQ-CP dated 14/10/2015 aim at creating conditions for enterprises to quickly absorb and develop new production technologies and for the public sector to develop e-government. Furthermore, regulations on export and import goods are to be simplified and modernized. Education in STEM and foreign languages as well as IT in general education are given priority. Autonomy in universities and vocational schools and new regulations on vocational and university training for specific industries are promoted.

- The 4G mobile communication network is to be improved, ensuring stable service delivery throughout the country from 2018. R&D on 5G networks is a focus to meet IoT requirements and thus enhance startup ecosystems to develop innovative entrepreneurship.

- The Ministry of Science and Technology promotes the National Proposal for Support to Innovation Startup Ecosystems toward 2025, as approved by the Prime Minister in Decision No. 844/QĐ -TTg on 18 May 2016, focusing on R&D, building and promoting applications, and transfer of key technologies of Industry 4.0.

- Vietnam's Ministry of Education and Training promoted the deployment of the STEM approach and offered experimental education in some secondary schools in the 2017–2018 academic year. There are also initiatives for capacity building for research and teaching in tertiary institutions to enhance basic skills, knowledge, creative thinking, and adaptability to the requirements of Industry 4.0.

- The Ministry of Labor is renovating training in vocational schools so that workers can operate efficiently within the technological environment of Industry 4.0. Solutions are sought to mitigate the influence and impacts of the Fourth Industrial Revolution on the structure of the labor market and the social welfare system, for example, through retraining courses for unemployed workers and setting job standards for different industrial sectors.

- The Ministry of Finance focuses on developing policies (e.g., tax preference) to encourage enterprises to invest in technology innovation activities and in R&D in the fields of IT and other advanced technologies.

- At the regional and local levels, provinces and cities also have specific policies. Bac Ninh province developed a pilot model of a smart city, along with investment in construction and high-tech agriculture. Bac Giang province designed a project on dissemination of science and technology to people through mobile phones. Ha Nam province strives to become a high-tech agricultural province with a high quality of production.

- A National Committee on E-Government was set up to achieve Vietnam's ambition of streamlining government procedures with online technologies. The new committee will develop strategies and policies to create a legal environment favorable to building and developing e-government, which will then pave the way for a digital government, digital economy, and digital society.

Integrated Assessment

Both Indonesia and Vietnam are nascent economies, meaning that their actual economic base is not especially strong in global comparisons, with special weaknesses in the capacity to build complex products (complexity capital). Drivers of future production are weak, as shown by low scores for R&D capacities. The two countries have set up comprehensive political agendas, reflecting this starting situation, to pave the way toward more intelligent production and Industry 4.0. In Indonesia, a careful analysis of sectors laid the ground for this strategy. In Vietnam, a broad range of regional initiatives seems to be an interesting feature of national policies.

It is unclear whether and to what extent these policies and initiatives have already brought about significant results, but it must be taken into account that there has not yet been enough time for the initiatives to take full effect. Furthermore, it is not evident whether sufficient (or any) evaluation procedures have been planned to systematically assess the impact of those initiatives and programs.

Critical Needs for Capacity Development for Industry 4.0 at National Level: Indonesia

Research by McKinsey uncovered a strange paradox in Indonesia: its digital occupants are among the most active in the world and it has a vibrant beginner ecosystem, but overall the country is lagging behind in embracing the benefits of modern technology. Weak ICT infrastructure and digital use are not evenly distributed within and between various business sectors. Connected Indonesian citizens understand technology, but Internet penetration is low.

The most urgent needs for capacity development are:

- Significantly increased investment in digital infrastructure, with special emphasis on cybersecurity, networking, cloud computing, data analytics, the IoT, automation, and digital work areas is called for.

- The government needs to increase budgets for R&D support significantly. Furthermore, there is an excessive number of government research institutions needing a new management and coordination approach.

- Cooperative R&D between R&D institutions and companies should be intensified to close the gap between R&D results and industrial exploitation of those results.

- In the educational system, the emphasis on STEM plus the arts (STEAM) needs to be even stronger. The linkages and matches between vocational schools and industries should be intensified.

- Government organizations need to become less bureaucratic and more responsive to actual challenges and needs in the economy and society.

- Technology transfer needs to be intensified. A good example of that is Schneider Electric's Smart Factory in Batam, Kepulauan Riau province. The government signed a memorandum

of understanding (MOU) according to which Schneider Electric will become a working partner of the Ministry of Industry in conducting training and mentoring for industry players as well as being a pilot plant for those who want to learn from the implementation of automation in Schneider Electric factories in Batam.

Critical Needs for Capacity Development for Industry 4.0 at National Level: Vietnam

For Vietnam, similar development needs as those for Indonesia can be identified:

- For digital infrastructure, the 5G IoT provides an enabling platform for Industry 4.0 to flourish. In a 5G IoT and Industry 4.0 environment, cybersecurity will become increasingly important, especially in relation to smart manufacturing where data security pertaining to intellectual property rights and protection of trade secrets becomes even more critical.

- R&D support is strongly needed. The government should issue policies to support and fund R&D in firms, especially domestic ones.

- In the education sector, new, more effective and efficient learning methods should be introduced as well as new technological subjects (AI, data analysis, robotics) to prepare young people for Industry 4.0 methods.

- Regarding labor market policies, the demand for and supply of specific knowledge should be closely surveyed and systematically forecast for the future.

- The education system needs to be better linked internationally, with the use of resources abroad to complement national educational institutions and programs.

- Technology transfer should be strengthened between foreign and national enterprises as well as among national enterprises.

- The innovation culture within companies should be strengthened by management. This will become more important if and when Vietnamese companies master more complex technologies themselves and must manage innovation of entire complex products/product systems.

Overall Integrated Assessment of the Nascent Economies

The critical development needs reflect the identified strengths, weaknesses, opportunities, and threats very closely. In both nascent economies, the core development needs are:

- Significant increases in investment in digital infrastructure, particularly cybersecurity, networking, cloud computing, data analytics, the IoT, and other technologies relevant to Industry 4.0.

- Increased budgets and policy support for R&D, focusing on cooperative R&D among companies and between industry and academia.

- New, more effective and efficient learning methods as well as new technological subjects in the educational system.

- Better links and matches between vocational education and industries.

- Stronger, more intensive technology transfer between foreign and domestic enterprises as well as among national enterprises.

Key Findings for the Legacy Economies: India and the Philippines

Assessment and SWOT Analysis
Core Results of the Domains (Contextual Conditions, Innovation Capability Elements)

Figure 5 shows the scores of the contextual condition indicators for the two legacy economies, India and the Philippines. The general pattern is rather similar to that found for the nascent economies (Figure 3). For example:

- The general manufacturing indicators and indicators specific to Industry 4.0 receive reasonably high scores, showing that manufacturing is an important, substantive sector in both economies and ICT-driven business models have gained relevance.

- Core weaknesses, as in the nascent economies, are low R&D and digital infrastructure scores in both countries (but more so in India than in the Philippines).

More specific results include:

- The Philippines have a relative strenght in the general education indicators, and India is strong in the education indicators specific to Industry 4.0.

- India has relative strength in labor market indicators, grounded in relatively high scores for the ability to attract and retain talent and for active labor market policies.

- India has even more pronounced strength in policy/governance indicators.

FIGURE 5

CONTEXTUAL CONDITIONS: INDIA AND THE PHILIPPINES.
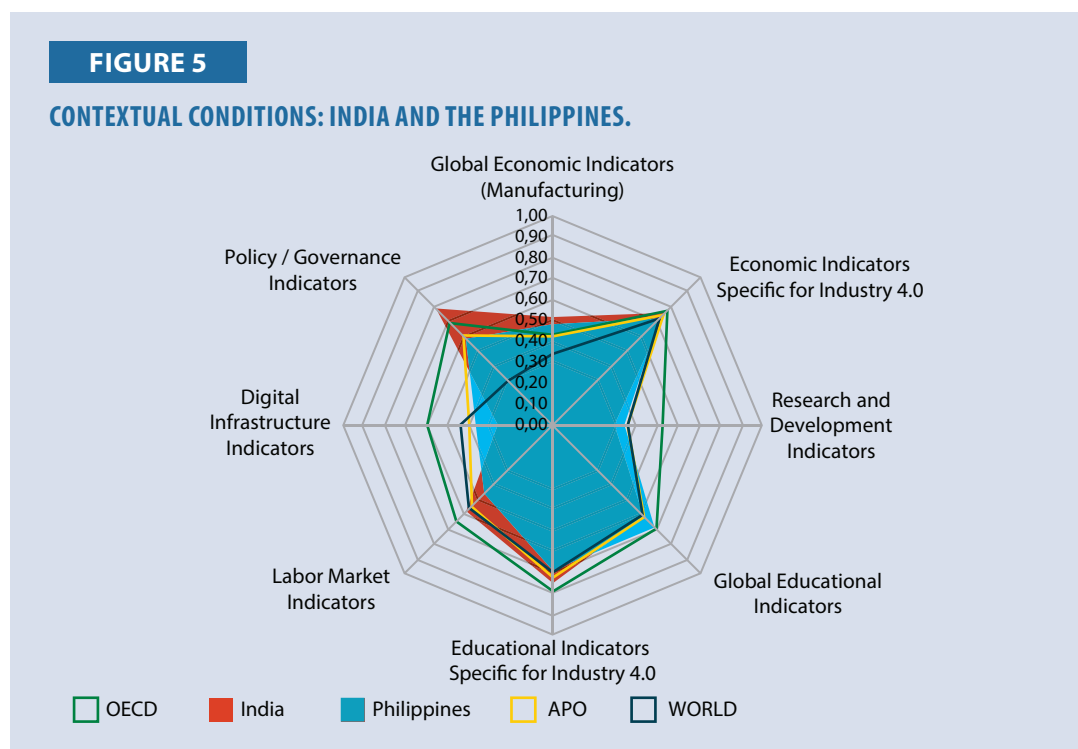
Figure 6 shows the innovation capability indicators for the two legacy economies. Again, similar to the nascent economies, the scores for complexity capital are low, indicating weak capacities for producing complex products. The human capital scores are modest, but higher than those of Vietnam.

India, similar to Indonesia, has strengths in structural and relational capital relating to information and idea sharing within companies and between companies and other companies or research institutions.

FIGURE 6

INNOVATION CAPABILITY: INDIA AND THE PHILIPPINES.

OECD   India   Philippines   APO   WORLD
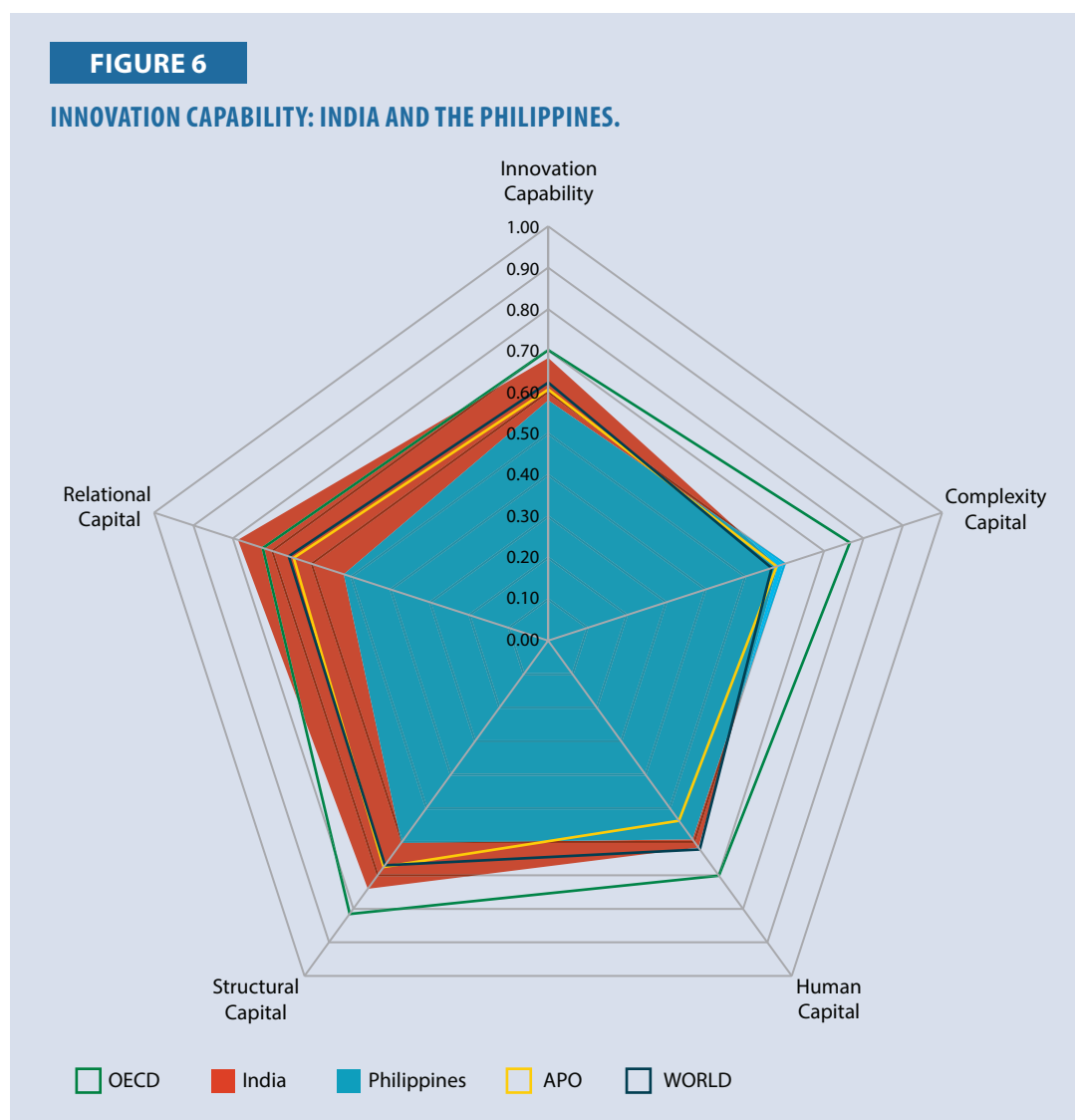
SWOT Analysis

Table 4 lists the strengths and weaknesses of India and the Philippines, as identified by national experts for India and for the Philippines.

Both countries have growing economies and a strong labor force. However, the two also show substantial economic disparities between regions and demographic groups. As already described by the quantitative parameters, the performance of India and the Philippines in R&D and innovation is weak. The national expert for India also identified a lack of innovation in the education sector and room for improvement in industry–academia cooperation as weak points.

TABLE 4

SWOT ANALYSIS PART 1: INDIA AND THE PHILIPPINES.

India and the Philippines: Strengths and Weaknesses		
Country	**Strengths**	**Weaknesses**
India	• **Rising economy** Excellent growth rate Strengthening manufacturing sector Growing automobile market Contribution of agriculture sector Decline in rate of inflation Largest FDI inflows Better tax compliance with GST • **Large human capital potential** Greater exposure to subject knowledge Strength of available manpower to bolster education system Low cost of education Huge number of higher educational institutes, especially vocational	• **Economic disparities** Low per capita income Unbalanced economic distribution Large gap between rural and urban areas Declining investment and savings with increasing income and consumption inequalities • **Low innovation dynamics in education** Lack of adequate upgrading of education system Lack of nationwide common curriculum and evaluation system Lack of industry–academia integration Lack of interdisciplinary courses Low teacher-to-pupil ratios
Philippines	• **Competitiveness advantages, comparatively high scores in:** Macroeconomic stability (43rd) Market size (32nd) Labor market (36th) Financial system (39th) Business dynamism (39th)	• **Competitiveness disadvantages, comparatively low scores in:** Institutions (101st) Health (101st) Innovation capability (67th)

Table 5 shows opportunities and threats for India and the Philippines, corresponding to the strengths and weaknesses. Both national experts find opportunities based on the economic strengths of the countries, which in India are specifically associated with infrastructure, aviation, and ICT-based startups in the agricultural sector. The threats relate to overcharged innovation and education systems and, specifically for Indonesia, institutional weaknesses.

Level of Industry 4.0 Integration into National Policies: India

The Government of India has established several relevant initiatives and programs like "Make in India," "Digital India," and National Policy for Advanced Manufacturing. A broad range of development programs is meant to bring about ICT-based innovation in rural regions and in the agriculture sector. A core requirement for this is the integration of more than 99% of the population into the AADHAR (personalized digital identity for citizens of India).

Among the programs for the agriculture sector are setting up a dedicated micro irrigation fund, establishing new mini labs in the Krishi Vigyan Kendras (KVKs) agricultural extension center, ensuring 100% coverage of all 648 KVKs in the country for soil sample testing, and expanding the coverage of the National Agriculture Market (e-NAM) from 250 to 585 markets. e-NAM is an online trading platform for agricultural commodities in India.

Specific measures include:

• Linking of AADHAAR with farmers' bank accounts.

• Issuing soil health cards.

TABLE 5

SWOT ANALYSIS PART 2, INDIA AND THE PHILIPPINES.

India and the Philippines: Opportunities and Threats		
Country	**Opportunities**	**Threats**
India	**• Economic opportunities** Develop one of the fastest-growing infrastructure sectors Fastest-growing aviation market Huge potential for agriculture-based startups Huge middle-class consumer base New avenues for imports from different countries **• Opportunities for the education system** Strategic engagement and capacity building in higher education Investment opportunities in unregulated and regulated segments Collaboration at national and international levels on areas of systematic reforms including quality assurance	**• Economic threats** Long lead time to start a business Fragile rural infrastructure Populism leading to fiscal deficits and poor quality of governance Fluctuating growth of exports, low share of industrial production **• Threats for the education system** Lack of interest of industries in developing collaboration in research Deteriorating standard of education due to low quality of intake (students) in institutions Poor enrollment ratio in higher and vocational education Few PhD candidates and low research quality
Philippines	**• Opportunities based on economic strengths** Develop sound strategy for Industry 4.0 based on established macroeconomic stability, market size, and favorable labor market and business dynamism conditions	**• Threats based on** Weak institutions unable to provide reliable frameworks and guidance Weak innovation capability overstressed by Industry 4.0 demands

- e-Choupal covering 6,100 installations in more than 95,000 villages serving four million farmers. e-Choupal is an initiative of ITC Limited, an Indian conglomerate, to link rural farmers directly to the Internet for procurement of agricultural and aquaculture products like soybeans, wheat, coffee, and prawns.

- The Trringo app for renting tractors.

- The KRISHI platform of TCS. TCS partners with wireless operators to allow farmers to download the platform on high-end phones, and TCS has set up "mini mobile sites" that farmers can visit to have the platform installed on low-end phones. Mobile phones overcome the lack of power and wired communication infrastructure in rural areas, enabling farmers to get one-on-one advice from experts. The platform technology not only allows farmers to submit questions to experts, but also provides environment-specific details that give the experts a kind of agricultural "map" of the issue involved.

Issues promoted related to Industry 4.0 in the Indian farming sector include:

- Supply chain management for perishable and nonperishable produce.

- Localized integrated irrigation systems.

- Drone monitoring at village level and micro-level data processing.

- Local food processing depending upon crops and real-time integration of production at national level.

The Government of India has set up plans to double the investment in digital infrastructure. Furthermore, e-governance is promoted within the public sector.

Level of Industry 4.0 Integration into National Policies: The Philippines
The Government of the Philippines has devised an inclusive innovation industrial strategy to better prepare the country for Industry 4.0. The overall goals are to:

- Build an innovation and entrepreneurship ecosystem aimed at upgrading and developing new industries.

- Remove obstacles to growth to attract investment and create jobs.

- Strengthen domestic supply chains and participation in global/regional value chains to link manufacturing with agriculture and services.

To facilitate this, the collaboration of government, academia, and industry is to be strengthened. Hopefully, this will result in the creation of new industries and clusters, upgrading of human resources development, and strengthening of MSMEs, all powered by innovation and entrepreneurship and facilitated by the ease of doing business.

Integrated Assessment
Like the nascent economies of Indonesia and Vietnam, the legacy economies of India and the Philippines have carefully assessed their specific national situations and set policies accordingly. Both recognize the importance of agriculture in the national economies, and their policies reflect this.

India has designed a range of programs and initiatives to help the agriculture sector and rural regions to take advantage of ICT by helping to develop useful digital tools (e.g., the app for tractor rental). This digitalization strategy for rural areas is based on AADHAR, the digital identity for citizens of India.

It is, however, unclear whether and to what extent those policies and initiatives have already made significant changes. There has not yet been sufficient time for the initiatives to take effect. Furthermore, it is not clear whether sufficient (or any) evaluation procedures are in place to systematically assess the impact of the initiatives and programs.

Critical Needs for Capacity Development for Embracing Industry 4.0 at National Level: India
Although India is predicted to become one of the largest manufacturing economies, cooperative R&D at company-to-company level and industry–academia interaction in R&D need to be improved at a faster pace. Furthermore, based upon the SWOT analysis, the following capacity development needs for fully embracing Industry 4.0 are obvious.

- In the economy:

    a. Support for small businesses in rural India by funding and systematic monitoring of progress and success.

    b. Reduction in lead time to start a business by providing more resources and optimized processes in public administration.

    c. Emphasis on better governance as compared with "popular" governance.

    d. Efforts to reduce trade imbalances by promoting exports of quality engineered products.

- In education:

    a. A nationwide system for framing curricula along with a nationwide evaluation system.

    b. A counseling system to guide students in selecting suitable courses for higher studies.

    c. Strong connection of the education system with industry requirements.

    d. Updating of curricula with a serious focus on training teachers.

    e. Permeability among various branches of vocational and higher education to balance enrollment and employability.

- In the labor market:

    a. Due to the high ratio of young people in the labor market, well-structured futuristic education and training programs are needed.

    b. Provide online matching platforms for potential employers and potential employees.

    c. Increase motivation for learning by better didactic design of courses, especially those relevant to Industry 4.0.

- In digital infrastructure:

    a. Increase the average Internet speed.

    a. Take a huge leap forward into broadband infrastructure.

    a. Set up stringent cybersecurity norms and follow-up protocols.

Critical Needs for Capacity Development for Embracing Industry 4.0 at National Level: The Philippines
Reflecting their similar socioeconomic situations, strengths, and weaknesses, the most urgent development needs in the Philippines do not differ markedly from those in India. However, no further detailed descriptions are possible because the national expert's report could not incorporate sufficient data.

Overall Integrated Assessment of the Legacy Economies

Despite their different socioeconomic backgrounds, the most urgent development needs of the legacy economies, India and the Philippines, are similar to those of the nascent economies, Indonesia and Vietnam. The comparable development needs are:

- Invest in digital infrastructure, with special emphasis on cybersecurity and average Internet speed, and on leapfrogging opportunities by a perhaps selective (regional, sectoral) leap forward to 5G networks.

- Strengthen science and R&D focusing on company-to-company cooperation and industry–academia interactions.

- Modernize education and training curricula, examinations, and teaching/learning methods.

- Develop better links and matching between vocational and higher education and industries.

Specific needs for India and the Philippines are related to expanding modern ICT applications to rural regions and the agriculture sector.

Key Findings for the Leading Economies: The Republic of China and Malaysia

Assessment and SWOT Analysis

Core Results of the Domains (Contextual Conditions, Innovation Capability Elements)

Unfortunately, several indicators are not directly available for the ROC, and some indicators were estimated, as explained in Annex B. Therefore, the quantitative results for the ROC should be regarded with caution.

Figure 7 shows the contextual condition indicators for the ROC and Malaysia. It can be seen that the scores are generally considerably higher than those for the nascent and legacy economies. Nevertheless, relative weaknesses regarding digital infrastructure are present. Those weaknesses are slightly more apparent for Malaysia. In terms of R&D indicators, only Malaysia shows relative weakness. The ROC, on the other hand, is characterized by comparatively high scores on the R&D indicators.

The following specific strengths can be identified:

- Both countries show strengths in the economic domain, especially regarding economic indicators specific to Industry 4.0.

- In the educational domain, especially in educational indicators specific to Industry 4.0, both have high scores, with Malaysia's slightly higher.

- In the labor market domain, both countries have high scores, with those of the ROC slightly higher.

- In the domain of policy and governance indicators, Malaysia's scores are outstandingly strong while those of the ROC are well above the relevant average.

FIGURE 7

CONTEXTUAL CONDITIONS: THE ROC (CONTAINING ESTIMATED VALUES) AND MALAYSIA.
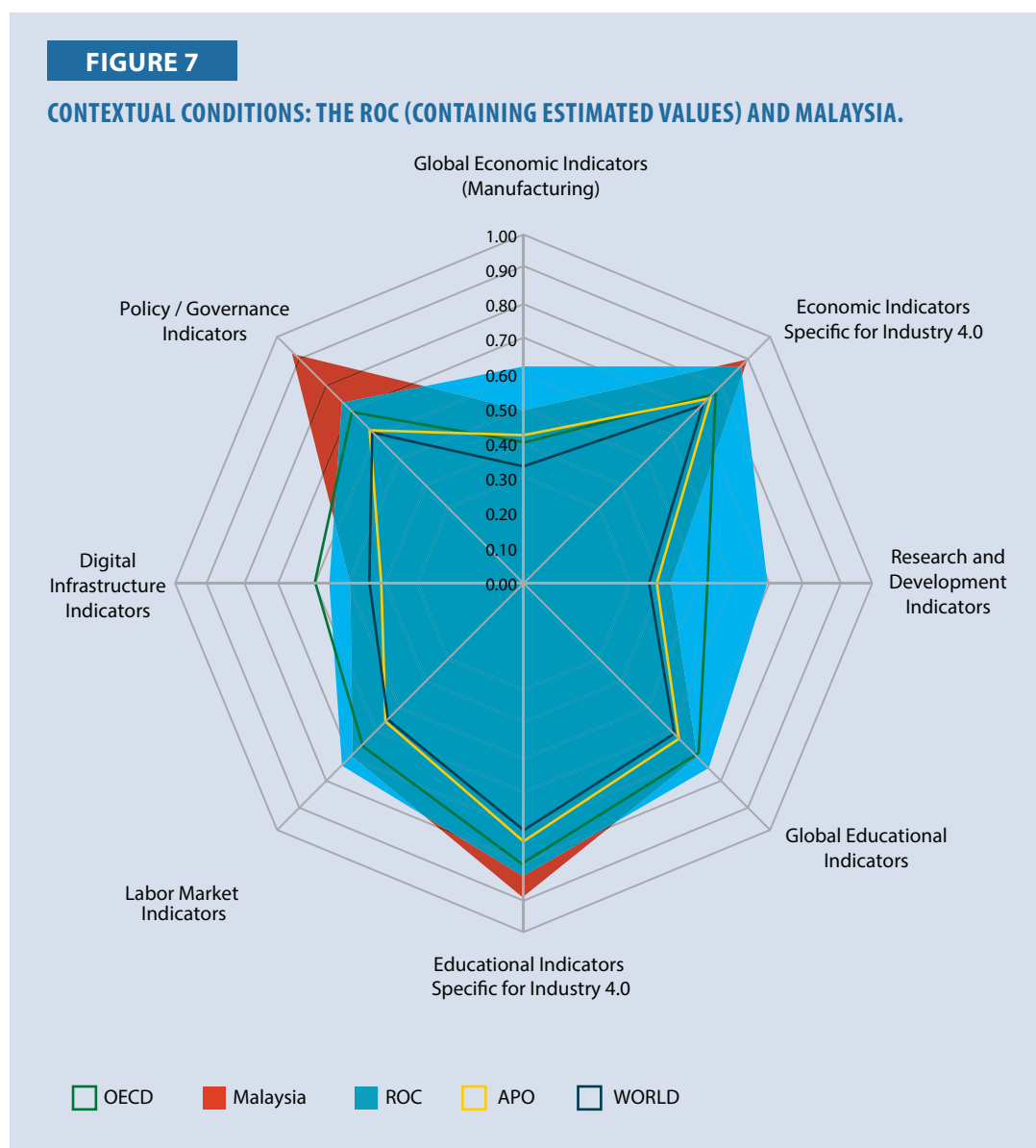
Figure 8 shows the results for the innovation capability elements. Three aspects are salient:

- The ROC and Malaysia score markedly better than the nascent and legacy economies in two of four innovation capability dimensions: complexity, and human capital. In terms of complexity capital, both are well above the APO average but still below the OECD average.

- Malaysia scores roughly as well as the nascent and legacy economies in the structural capital indicators, whereas the ROC scores higher.

- In the domain of relational capital, Malaysia performs worse than the nascent and legacy economies, but the ROC performs better.

SWOT Analysis

Table 6 lists the strengths and weaknesses of the ROC and Malaysia, as identified by national experts.

FIGURE 8

INNOVATION CAPABILITY: THE ROC (CONTAINING ESTIMATED VALUES) AND MALAYSIA.
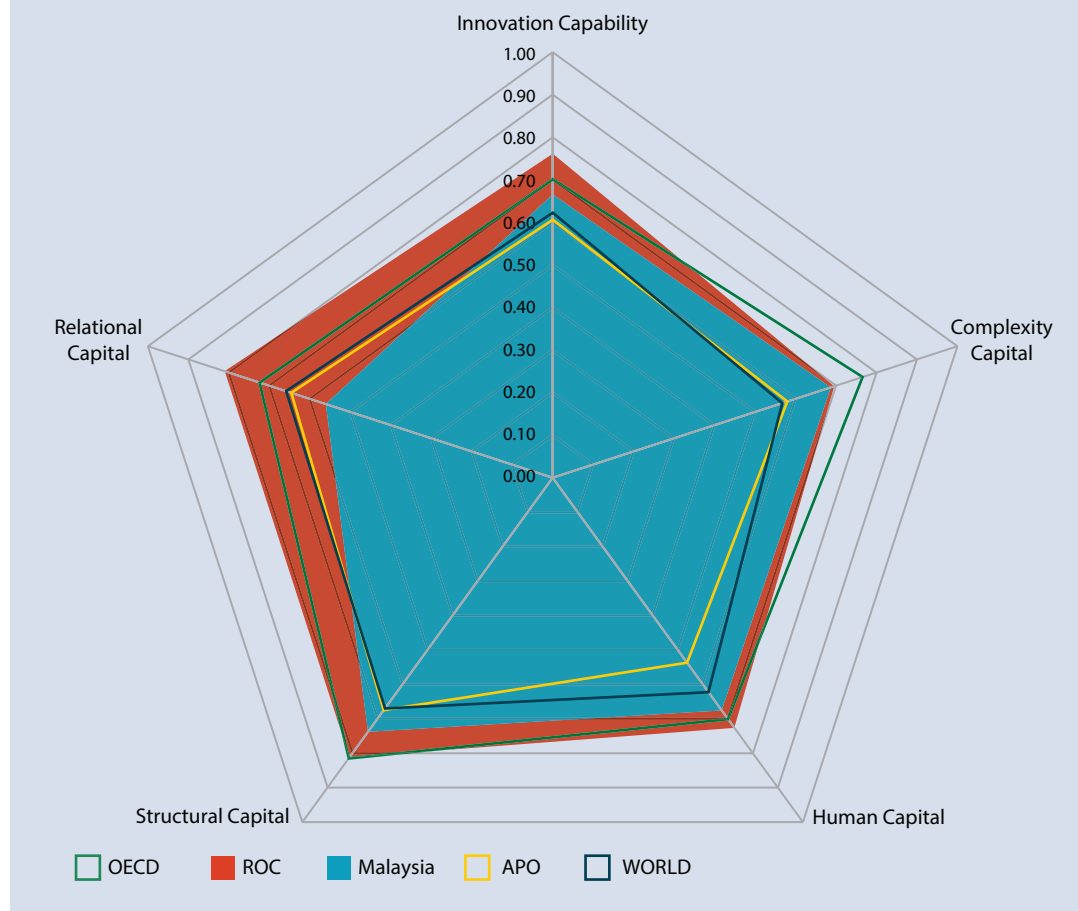
Both countries, as leading economies, have strengths in the economic and technological domains. In the ROC, a very sophisticated profile of competencies in high-end machine building as well as ICT hardware/semiconductors can be identified.

Malaysia has a structured economy and strong education system, in general terms as well as in aspects more directly related to Industry 4.0. It even has a dedicated Industry 4.0 policy (Industry4WRD), which it uses to systematically transform industry. Apart from that, it continues to grow an inclusive digital economy as well as supporting new game-changing, innovative industries such as remanufacturing and precision agriculture. Additionally, the country has outstanding experience with highly effective learning methods like Problem Based Learning (PBL).

Among the weaknesses of the ROC are relatively lower scores in industrial software and system integration, in the domain of (basic) research, and in vocational and technology-related education. Malaysia scores relatively low in the domains of innovation capability (especially cooperative R&D and relational capital, Figure 8), infrastructure, ICT adoption, and health. One of the major concerns here is the digital gap that exists between Malaysian states, especially between modern, developed states and those that are less developed. It also has many manufacturing SMEs operating with capacity to spare, thus making scalability a nonissue. Moreover, it has a complex technical and vocational education and training system that is currently undergoing streamlining and reform.

TABLE 6

SWOT ANALYSIS PART 1: THE ROC AND MALAYSIA.

ROC and Malaysia: Strengths and Weaknesses		
Country	**Strengths**	**Weaknesses**
ROC	• **Very competitive in Industry 4.0-related hardware, including semiconductors, ICT, and precision machinery** State of cluster development (top 5) • **Very strong manufacturing domain know-how** Manufacturing valued added to the economy (top 4) Manufacturing output (top 7) Productivity per capita (top 7) • **Very dense Industry 4.0-related advanced technology, such as cyberphysical systems, IoT, etc.** R&D expenditure (top 2) Patent applications (top 5) High-tech exports (top 3) • **Very attractive Industry 4.0-related talents** Higher education achievement (top 4) Diversity of workforce (top 6)	• **Not very competitive in Industry 4.0-related software, system integration, and innovative services** Manufacturing value added (13th) ICT-enabled business models (23rd) Growth of innovative companies (28th) • **Not very powerful in essential invention and pioneering science** Scientific publications (29th) High-tech patent grants (14th) Multistakeholder collaboration (23rd) • **Not a leading Industry 4.0-related educational system, academic or on-the-job** Total public expenditure on education (47th) Critical thinking in teaching (30th) Quality of vocational training (36th) Digital/technological skills (40th) Willingness to delegate authority (37th)
Malaysia	• **Good competitiveness scores** 25th in the 2018 Global Competitiveness Report (total score 74.4%) From the 12 pillars measured in the GCI 4.0, Malaysia ranks among the top 25 for 8 pillars: Macroeconomic stability (1st) Financial system (15th) Business dynamism (19th) Labor market (20th) Market size (23rd) Institutions (24th) Education and skills (24th) Product market (24th) • **Very well-developed education system** Experience with advanced learning methods like PBL Well-developed continuing education system	• **Relative weaknesses in four competitiveness pillars** Innovation capability (30th) Infrastructure (32nd) ICT adoption (32nd) Health (62nd) • **Complicated governance structure in TVET** Seven ministries involved in TVET; currently under reform

FTAs, free trade agreements; CPTPP, the Comprehensive and Progressive Agreement for Trans-Pacific Partnership; RCEP, the Regional Comprehensive Economic Partnership; TVET, technical and vocational education and training.

Regarding opportunities, both the ROC and Malaysia are counting on their good positions in the overall economy and technology. The ROC would profit from an increased demand for Industry 4.0-related ICT components, of which it is a globally leading purveyor. Furthermore, it could take the roles of both leading user and leading supplier of technologies related to Industry 4.0.

TABLE 7

SWOT ANALYSIS PART 2: THE ROC AND MALAYSIA.

ROC and Malaysia: Opportunities and Threats		
Country	**Opportunities**	**Threats**
ROC	• **Global need for Industry 4.0-related ICT components means that the ROC is:** No. 1 in semiconductor foundry No. 2 in integrated circuit design No. 3 in wireless local area networks • **Worldwide manufacturing bases fit dual winning strategies:** Leading users: implement Industry 4.0 solutions to increase competitiveness in quick response, flexibility, and precision Leading suppliers: polish Industry 4.0 solutions and globally promote them to provide solution and service value	• **Competition valley** Lower cost than leading countries, e.g., Germany, Japan Following countries to upgrade technology, e.g., PR China, "firm-level technology absorption" index (29th) Higher value than peer countries, e.g., ROK, "companies embracing disruptive ideas" index (27th) • **Tariff barriers due to special international situation (very few FTAs; neither in CPTPP nor RCEP)** • **Weak talent acquisition competition due to lower salaries than competitors** "Country capacity to attract and retain talent" (37th) and "knowledge-intensive employment" (39th) indexes • **Disadvantaged 5G competition in industry verticals, such as Industry 4.0, due to low 5G R&D investment** "Investment in telecommunications" index (45th)
Malaysia	• **Capitalize on excellent competitiveness scores:** Good scores across a broad range of competitiveness factors provide sound basis for adoption of new technologies like Industry 4.0 • **Increase leading position in education** Long-standing experience with advanced learning methods and well-developed continuing education system provide hard-to-copy competitive advantage regarding core capacities for Industry 4.0	• **Weaknesses in important domains like innovation capability and ICT adoption spoil competitive advantage specifically in innovation-intense domains like Industry 4.0** • **Reform of governance structure in TVET may prove ineffective and thus harm core competitive edge**

Malaysia, on the other hand, builds on its Industry4WRD policy by developing a conducive Industry 4.0 environment as well as attracting foreign investment. Although it promotes other high value-added manufacturing sectors, the electrical and electronic industry has consistently received more attention from the Malaysian government and continues to benefit from incentives. Nevertheless, the government also strongly supports technology startups and has set up a vibrant ecosystem with agency-backed platforms and activities. Malaysia even has dedicated Industry 4.0 incubators (such as the MTDC's Center of 9 Pillars, Co9P) and promotes the creation of a variety of spin-off companies.

Threats to the ROC may stem from an increasingly precarious market position between leading suppliers pricing down and following countries increasing their technological levels. The step forward to 5G networks, which is essential for advanced Industry 4.0 applications, may be hindered by low investments.

Malaysia faces a significant threat because its own industries do not take full advantage of the incentives and programs available under the Industry4WRD policy. This might be due to the poor understanding of the real benefits and focus of Industry 4.0, being sidetracked by solution providers who package non-Industry 4.0 solutions as actual Industry 4.0 solutions, and failing to understand the importance of a holistic transformation strategy. The latter would in turn reflect in a failure to reskill employees for Industry 4.0 and insufficient investment in business models and product innovation. Malaysian industries also often associate Industry 4.0 transformation with heavy investments in new machinery and systems, whereas there is a cost-effective method by utilizing the remanufacturing industry to retrofit existing machinery into Industry 4.0-ready systems.

Level of Industry 4.0 Integration into National Policies: The Republic of China

The ROC follows a mission-based vision centered on smart machinery, with two perspectives focusing on makers and users, respectively:

1. Smart machinery as an industry

   • Maker-side thinking.

   • Increase the value and competitiveness of the machinery industry through the integration of precision and smart technologies.

   • Construct a smart machinery ecosystem for one-stop shopping with domestic and international makers (strategy of leading suppliers).

2. Industries with smart machinery

   • User-side thinking.

   • Increase the value and competitiveness of the manufacturing industry through smart machinery solutions (strategy of leading users).

   • Conduct proof of system and business in the ROC and then promote business abroad based on the expected success stories of selected key industries as solution providers of production systems (strategy of from leading users to leading suppliers).

As an example of national/regional cooperation, the ROC's Ministry of Economic Affairs, Ministry of Science and Technology, and Ministry of Education cooperate with a local government (Taichung City) to achieve the following:

1. Local linkages

   • **Strategic thinking:** To construct an ecosystem of companies, universities, and research institutes for the synergy of multiple stakeholders and magnification of industry impacts.

   • **Tactics no. 1 and no. 2:** To build a smart machinery city and integrate human resources.

   • **Major achievement:** Smart machinery demonstration site equipped with domestic machines and solutions from multinational corporations.

2. Future linkages

- **Strategic thinking:** To establish industries' leading core competences in smart solutions for the near- and long-term future.

- **Tactics no. 3 and no. 4:** To create the capacity of leading enterprises and to improve the capabilities of SMEs.

- **Major achievement:** Smart machine box (SMB) for 1,300 facilities from eight industries successfully online.

3. Global linkages

- **Strategic thinking:** To strengthen technology and then business partnerships and vice versa.

- **Tactics no. 5 and no. 6:** To enhance joint technology R&D and to promote the New Southbound Policy.

- **Major achievement:** R&D cooperation with multinational corporations, such as Siemens, Dassault Systemes, Rockwell Automation, and Mitsubishi Electric.

To foster more interdisciplinary talents, with bottom-up activities and top-down funding, smart machinery professional training in the ROC focuses on two mutually reinforced aspects with four activities.

1. Manpower cultivation and assessment

- **Strategic thinking:** To directly foster qualified smart machinery talent for industry.

- **Activity 2:** Establishing smart machinery institutes.

- **Activity 4:** Industrial Professional Assessment System.

- **Looking ahead:** A national certification system for smart machinery should be created, especially an internationally recognized one.

2. University–industry cooperation

- **Strategic thinking:** To jointly develop high-quality smart machinery talent targeting industry needs.

- **Activity 1:** Fostering talent and potential professionals.

- **Activity 3:** Training alliances/knowledge-based platforms.

- **Looking ahead:** Smart machinery curricula should be developed under a long-term, e.g., 10-year, project. A one-shot project may not contribute as significantly.

Smart machinery promotion in the ROC aims at developing both large manufacturers and SMEs through bottom-up activities and top-down funding, as described below.

1. **For large manufacturers:** Enable large enterprises to create leading technology in smart manufacturing and smart products.

   - **Strategic thinking:** To fund multistakeholder integrated projects on R&D and pilot lines for upgrading related value chains from component providers, to manufacturers, to system integrators (SIs).

   - **Activity 1.1:** Theme-based R&D projects for several value chains to develop smart solutions not only for production lines and factories but also for the required components and machines.

   - **Activity 1.2:** Pilot industry program for several value chains to construct smart production lines or factories.

   - **Achievements (2018):** In joining theme-based R&D projects, 13 manufacturers invested NT$2.23 billion in three years. In participating in pilot industry programs, 20 manufacturers from six industries in four domains invested NT$9.3 billion in three years with an estimated revenue increase of more than NT$15 billion.

2. **For SMEs:** Improve the capabilities of SMEs for digitalization.

   - **Strategic thinking:** To develop national networking devices and IoT platforms for SMEs in various industries and of different sizes to digitize their shopfloor data and create value through cloud computing.

   - **Activity 2.1:** Developing the SMB for equipment networking and data storage/management.

   - **Activity 2.2:** Developing the National IoT Platform (NIP) for SMEs to deploy and execute their high-performance, high-stability, high-capacity cloud applications.

   - **Achievements (2018):** Sixty-one SMB applications were approved with 1,300 facilities online. Furthermore, NIP best practices have been established in several leading companies such as one of the largest PCB suppliers.

To establish a concrete smart manufacturing system for encouraging SME investment in Industry 4.0 with bottom-up activities and top-down funding, a smart manufacturing demonstration site was established in Taichung City. This site can provide services of rapid proofing and mass production trials for SMEs.

To provide onsite advisory and diagnostic services for SMEs with bottom-up activities and top-down funding, a smart manufacturing consulting team has been built and operated with SIs and technical experts from industry, academia, and research institutions. Among the achievements of 324 successful services for metal, mechanical, electrical, and other industries, 18% of participating SMEs have solid plans to upgrade their smart solutions with their own investment of NT$855 million and government funding support of NT$698 million.

Level of Industry 4.0 Integration into National Policies: Malaysia

Malaysia consistently budgets for digitalization efforts. In 2019, it had allocations for technology and Industry 4.0, including:

- Promotion and development of e-sports and the computer gaming industry.

- Implementation of the National Fiberisation and Connectivity Plan (NFCP).

- Ensuring reductions of at least 25% in broadband prices.

- An allocation to assess 500 SMEs on their Industry 4.0 readiness over three years.

- An Industry Digitalization Transformation Fund at a subsidized incentive of a 2.0% interest rate.

- A Green Technology Funding Scheme with a subsidized incentive of a 2.0% interest rate.

For 2020, Malaysia planned to:

- Double the allocation for e-sports and the computer gaming industry.

- Strengthen the NFCP with additional long-term funding through a public–private partnership program.

- Allocate additional automation incentives and grants for 2,000 manufacturing and manufacturing-related service companies.

- Offer matching grants to digitalize operations to 100,000 SMEs.

- Offer matching grants to develop drone delivery, self-driven vehicles, and blockchain applications.

- Set up 14 one-stop digital enhancement centers meant to help SMEs in their digitalization journeys.

- Establish three digitally enhanced libraries.

- Allocate training funds to develop new digital economy entrepreneurs including micro digital ones.

- Allocate additional funding to its equity crowdfunding arm.

- Promote the mass adoption of e-wallets by making a one-time deposit to Malaysians in a certain income category.

Malaysia is also planning to introduce a digital bank framework as well as promote digital social responsibility by providing tax incentives to companies with such activities.

Malaysia's national policy Industry4WRD was launched in 2018. It was later strengthened with the Shared Prosperity Vision and National Entrepreneurship Policy 2030. In 2020, the National Agriculture Policy was being revised to include Industry 4.0 developments in agriculture and agroindustries, and the Fourth Industrial Master Plan (IMP4), which was still under development, is expected to include next-generation agile manufacturing as well as digitalization provisions. Under the Industry4WRD policy, there are three main objectives:

1. Attract stakeholders to Industry 4.0 technologies and processes and increase Malaysia's attractiveness as a preferred manufacturing location.

2. Create the right ecosystem for Industry 4.0 to be adopted and aligned with existing and future development initiatives.

3. Transform Malaysia's industry capabilities in both a holistic and an accelerated manner.

The targeted outcomes of this policy are greater contributions by the manufacturing sector, more high value-added products, and continuing FDI.

The framework of Industry4WRD is based on a 10-year vision in which Malaysia becomes the primary destination for high-tech industry, is a strategic partner for smart manufacturing and related services in the Asia-Pacific, and becomes a total solution provider for advanced technology. In achieving this vision, specific goals guide and measure the progress of the transformation:

- Labor productivity growth (30% increase).

- Manufacturing contribution to the economy (from RM254 billion to RM392 billion).

- Greater innovation capacity (becoming one of the top 30 nations).

- Greater proportion of high-skilled jobs (from 18% to 35%).

A set of shift factors (people, process, and technology) will be optimized in order to achieve the goals, and these factors are in turn dependent on the following enablers: funding and outcome-based incentives; enabling ecosystem and efficient digital infrastructure; regulatory framework and industry adoption; upskilling existing and producing future talent; and access to smart technologies. A total of 13 strategies supports these enablers.

For strategies that relate to funding, the Ministry of Finance, Ministry of Economic Affairs, Ministry of Trade and International Industry, Bank Negara Malaysia (Central Bank), and Securities Commission Malaysia are involved. Among the activities are the introduction of tax incentives and innovative financial products.

For strategies related to infrastructure, the Ministry of Communication and Multimedia, Ministry of International Trade and Industry, Malaysian Administrative Modernization and Management Planning Unit (MAMPU), and Malaysia Digital Economy Corporation (MDEC) will be involved. The activities aim to strengthen the connection among industry, education, and training hubs; digitalize government processes; and link service providers to manufacturing firms.

For strategies related to regulations, the Ministry of International Trade and Industry, Malaysian Communication and Multimedia Commission, MAMPU, and Cybersecurity Malaysia will be involved. Activities will include the creation of an Industry 4.0 capability assessment platform, improvement of data integrity, and increasing the awareness of the needs, benefits, and opportunities of Industry 4.0.

For strategies related to skills and talent, the Ministry of Education and Ministry of Human Resources will be involved. Among the activities planned are reskilling and upskilling of the workforce and ensuring the availability of future talent.

For strategies related to technology, the Ministry of International Trade and Industry, Ministry of Education, and the Ministry of Energy, Science, Technology, Environment, and Climate Change will be involved. Activities include establishing digital or technology labs (especially through public–private partnerships), setting industrial standards for Industry 4.0, and intensifying research, innovation, commercialization, and entrepreneurship programs that support and advance priority sectors.

Apart from the above, other ministries, e.g., Ministry of Entrepreneurship Development, Ministry of Agriculture, and government agencies, e.g., Malaysia Technology Development Corporation MTDC, are actively promoting the adoption of Industry 4.0. As an example, the MTDC, which has funded hundreds of Malaysian startups and companies, launched its Industry 4.0 hub called the Center of 9 Pillars (Co9P) in November 2018. In this hub, the center partners with six organizations: MyEdtech Community; Malaysian Robotics and Automation Society; Malaysia Internet of Things Association; Research Triangle Institute; Human Life Advancement Foundation; and RESPECT Business and Advanced Technology Solutions S/B.

Critical Needs for Capacity Development for Industry 4.0 at National Level: The Republic of China

According to the SWOT analysis results (Tables 6 and 7), the critical needs of the ROC are:

1. **High-value manufacturing:** Although the ROC's "manufacturing value added in the economy" ranks in the top 4 and "manufacturing output" ranks 7th, its "manufacturing value added" only ranks 13th. The four main reasons are:

    •   Few ICT-enabled business models (23rd).

    •   Slow growth of innovative companies (28th).

    •   It is stronger in components and commodity providers (refer to the ROC's world-leading top three products) but weaker in solution providers.

    •   Lack of emphasis on the legal framework and long-term vision in Industry 4.0-related national policies, referred to as the "future orientation of government" (67th).

2. **Competitive patents:** Although the ROC ranks in the top 5 in "patent applications," it only ranks 14th in "high-tech patent grants." This situation will gradually influence its market share related to Industry 4.0.

3. **Digital talent:** Although the ROC's "higher education achievement" ranks in the top 4, its "digital skills among the population" and "digital/technological skills" only rank 25th and

40th, respectively. This seriously affects the planning, implementation, and dissemination of Industry 4.0 solutions inside and among companies. The three main reasons are:

- Relatively low public expenditure on education (47th).

- Room for improvement in the quality of vocational training (36th).

- Not very effective internal training and sharing by companies, as indicated by "willingness to delegate authority" (37th) and "multistakeholder collaboration" (23rd).

Similar to Malaysia, there is also weakness in multistakeholder cooperation in R&D.

Additional information regarding critical needs can be derived from CommonWealth Magazine Taiwan Industry 4.0 survey (29 October–30 November 2018; 1,887 questionnaires issued, 566 returned). According to those data, critical needs are:

1. Cybersecurity: Only 11% of companies passed cybersecurity certification.

2. Digital platforms (digital factories, stores, or service platforms): Only 5.9% have mature digital platforms.

3. Machine data analysis: Only 13.9% make effective use of machine data for prediction and improvement.

Critical Needs for Capacity Development for Industry 4.0 at National Level: Malaysia
Although Malaysia has sound policies on Industry 4.0, several areas could be improved.

1. **Understanding actual Industry 4.0:** The promotion of Industry 4.0 by the government and the substantial budget allocated for it have made Industry 4.0 the flavor of the week for many consultants, trainers, and solution providers, some of whom do not have the required competencies to offer Industry 4.0 services and/or wrongly package non-Industry 4.0 solutions as Industry 4.0 solutions. Steps are therefore needed to ensure that stakeholders at government and industry levels truly understand the requirements and spirit of Industry 4.0 and how it correlates with intelligence, connectivity, and data analysis. Failure to have a good understanding of Industry 4.0 or its benefits could result in investment in the wrong areas, the creation of white elephants, and/or case studies with poor results, all of which will cause the sector to shy away from Industry 4.0.

2. **Promotion of competent local solution providers:** Malaysia has a very structured method to assess the readiness of organizations performing manufacturing and/or manufacturing-related services. Assessed organizations receive a detailed analysis report and should take necessary actions to minimize gaps. At present, there are funding mechanisms by the government to promote the adoption of responsible smart automation, but there are no mechanisms to promote the use of competent local solution providers to minimize gaps even though these players have capabilities similar to those of established foreign players. Supporting local players will not only be good for the economy but also have positive impacts on domestic knowledge creation and retention as well as the local research environment.

3. **Creation of more scientific and technical employment:** Although Malaysia has numerous science graduates and has taken steps to promote STEM, there are not enough employment opportunities in the industry for science graduates at present. Industries must move to create an innovative working environment to come up with smart products for society and to remain competitive in the digital market. Industries are also in critical need of an ecosystem that utilizes and analyzes data. These shifts must translate into new scientific and technical job opportunities, and the practice of outsourcing technical work to foreign companies must stop.

4. **Making TVET and jobs a first choice:** Malaysians tend to view TVET as an inferior choice to university education and wrongly associate TVET with low-income jobs and/or jobs with no clear career path and growth. Not only does this thinking balloon university intake, it also demotivates students in the TVET line. In the era of digitalization and virtualization, smart machines, and widespread automation, TVET graduates will have similar job opportunities as university graduates and will command equivalent respectable salaries. The TVET reform that is taking place in Malaysia is timely and must emphasize allocating sufficient funding to strengthen: 1) the quality of TVET to ensure that the characteristics of its graduates fit the requirements of a digital economy; and 2) a career track for TVET graduates supported by industry.

5. **Increasing the commercialization of research:** The number of research projects in Malaysia is increasing, with universities and research institutes making good progress in publications and winning many research grants from local and foreign governments and industries. However, commercialization activities need to be improved significantly as this would demonstrate to the industry at large that research programs can also be in the form of applied research (as opposed to theoretical and fundamental research) and their results can be monetized. Furthermore, by putting focus on increasing the number of patent applications, not only will Malaysia fare better in the GCI 4.0 rankings, it will also create a vibrant research environment focused on innovation. Researchers in universities and research institutes also need to have a shift in mindset and think along the lines of return on investment and internal rate of return. In the end, Malaysia needs more positive case studies on commercialization of research to persuade most industries to start programs of their own and begin collaborating with local universities and research institutes.

6. **Creation of more research consortiums:** As described in the previous point, Malaysia has a positive, growing research environment. Apart from the increase in commercialization efforts, Malaysia also needs to have more focused programs under consortiums made up of researchers (from multiple universities and institutes) as well as researchers/engineers from industry (from multiple companies). The structure of such consortiums can be loosely based on the NASA EPSCoR model to tackle mega topics essential for Digital Malaysia: urban mobility; a digital productivity backbone; drone mobility and delivery; and next-generation agile manufacturing and distribution. The formation of the Research Management Agency under the 2020 budget is a first step toward this coordination.

Overall Integrated Assessment of the Leading Economies

Both leading economies, the ROC and Malaysia, have set up extremely sophisticated political strategies and programs, encompassing the whole range of necessary domains from infrastructure

and R&D to education and technology transfer based on profound and consistent analyses of the countries' specific positions in terms of Industry 4.0. Budgets and target marks are assigned to the individual initiatives and projects. Bottom-up as well as top-down initiatives work together in a synergistic manner.

It is, however, not completely clear whether and to what extent these policies and initiatives have already had significant effects, since there has not yet have been enough time for the initiatives to take full effect. Furthermore, it is not evident whether sufficient (or any) evaluation procedures have been put in place to systematically assess the impact of the initiatives and programs.

Integrated Assessment of All Six Economies

There are some very country-specific indicators relating to the ROC addressing its weaknesses in high-value manufacturing and competitive patenting. Other development needs like promoting digital talent in the education sector and stimulating cooperative R&D in the innovation sector are shared by several countries. Specifically, the need to improve education in technology domains and vocational education in general seems to apply to all nascent, legacy, and leading economies.

In addition, the necessity of encouraging not only R&D in general but also cooperative R&D among companies and between industry and academia seems especially apparent in the leading economies to compensate for their weaknesses in relational capital. Nascent and legacy economies, although they score fairly high for relational capital, nevertheless also need intensified R&D cooperation to nurture and extend their strengths.

RECOMMENDATIONS

Recommendations for the Nascent Economies: Indonesia and Vietnam

Governments and Public Agencies

R&D, Innovation, and Industrial Policies: Indonesia

In implementing the Making Indonesia 4.0 program, the government identified five manufacturing sectors prioritized for development: 1) food and beverages; 2) textiles and clothing; 3) automotive; 4) chemicals; and 5) electronics. Their prioritization was based on past performance, especially contributions to GNP and labor absorption. Given that there is so much potential for improvement in Indonesia, it is recommended that sector selection be carried out by looking at future opportunities that have not yet been addressed, such as the marine sector and creative industries.

Indonesia's current R&D budget is too low at 0.2% of GDP. In the Making Indonesia 4.0 roadmap, the research budget is targeted at 2.0% so that it is equivalent to that of developed countries. It is recommended that an increase in the research budget be accompanied by a well-planned roadmap so that the research actors obtain clear guidance on the priority areas to be developed. The research master plan that has been prepared should be integrated to support the sectors that will be built up under Making Indonesia 4.0.

R&D institutional arrangements need to be aligned with increasing budgets. Existing R&D institutions are too numerous, and coordination among them is lacking. Rearrangement is suggested by combining similar institutions and/or organizing activities and R&D budget allocations in an integrated manner (one-door policy) to support the development of the targeted sectors under Making Indonesia 4.0.

The participation of the industrial sector and businesses in R&D activities, which is still around 25%, should be increased. The R&D dominance of government research institutions and universities has led to a situation where research results do not contribute to industrial development. It is recommended that research institutions or universities be required to partner with industry and business actors. The obligation to partner is addressed in the implementation of many research incentive programs provided by the government, especially by the Ministry of Technology Research and Higher Education.

Increased industry participation in R&D is recommended to continue and be encouraged through tax and fiscal reduction incentives for industries that carry out their own research or collaborate with universities or R&D institutions. These incentives can also be prioritized for the manufacturing sectors that are included in Making Indonesia 4.0.

The lack of smooth relations between the world of research (producers) and the business world (users) is thought to be due to the lack of legislation to regulate the relationship. What is available is the National System for Research, Development and Application of Science and Technology (Law 18/2002), which regulates science and technology development. It is recommended that amendments to Law 18/2002 be directed more toward building an innovation system that regulates

industrial development through the contribution of science and technology, rather than simply building science and technology capabilities.

R&D, Innovation, and Industrial Policies: Vietnam

First, the Government of Vietnam should enhance encouragement and support for enterprises that invest in R&D fields like technological innovation, promote the development of science and technology development funds by enterprises, and increase linkages between enterprises and science and technology organizations in carrying out scientific and technological tasks. The government should not only support science and technology through the establishment of venture capital funds in special areas such as Hanoi, Ho Chi Minh City, Quang Ninh, and Binh Duong but also focus on investment capital in priority areas like IT, new materials, manufacturing mechanics, and biotechnology. The government should encourage the transfer and application of science and technology, especially in high-tech areas and special industrial zones; complete regulations on procedures for recognition of science and technology enterprises; approve financial regulations for R&D activities and diversify financial resources for science and technology enterprises; and issue regulations on science and technology incubation activities.

Second, regarding the national innovation system, it is necessary to create fundamental changes with policies to encourage businesses to invest in science and technology and accept risks. This can be brought about by science development funds, science nursery funds, and R&D funds from both nonprofit and for-profit organizations. Solutions should be implemented to improve the absorption and technology development capacity of enterprises; build test centers to receive, test, and deploy new technologies; and devise investment and divestment policies for venture capital in Industry 4.0-oriented startups.

Third, the government should accelerate the process of institutional reforms on innovation such as the legal framework for enterprises, Competition Law, and conditions for accessing financial resources. These legal frameworks need to be completed and stabilized for businesses to invest in R&D activities. Moreover, direct capital support or tax incentives would encourage businesses to undertake R&D. The government should promote the implementation of policies to attract FDI in high-value production.

Fourth, the government should encourage both domestic and international organizations to invest in Vietnam's digital infrastructure. The development of IT infrastructure should focus on: expanding the information highway to every corner of the country, ensuring the connection of machinery and equipment components with data, processes, and people; encouraging enterprises to invest in new technologies like 5G; and building a data center to serve domestic demand. Moreover, enactment of the Law on Cybersecurity will provide new methods for controlling IT security, online shopping, and the prevention, detection, avoidance of, and dealing with acts that infringe cybersecurity. The Law on Cybersecurity will create a legal framework and tools for the state to protect the interests of participants in the economy.

Fifth, to improve collaboration among businesses, the Government of Vietnam should provide forums for each industrial sector, establish associations and organizations for each field, encourage businesses to exchange R&D results and transfer technology, and protect patents. For improving collaboration between academia and business, the government should help schools to connect with businesses and businesses to contract universities to conduct research and testing for the transfer of scientific research results. In addition, business models should provide funding for research,

application of research results, and acquisition of new technologies. Business schools can reduce the gap between the commercial sectors and education in demonstrating impact in several ways: through relevant collaborative research that is meaningful and valuable to business and industry; through quality higher and graduate education to address innovation topics such as research translation and commercialization, the digital economy, and business processes; becoming central hubs for business and industry to access university expertise and partners across faculties and disciplines; and continuing to build on their reputation in international education and establishing business networks with international graduates.

Educational and Labor Market Policies: Indonesia

In entering the Industry 4.0 era, a problem that arises is the impact on employment. Automation, mechanization, and various uses of technology can replace human labor and result in unemployment. To deal with this, a comprehensive study needs to be carried out for each manufacturing sector to determine to what extent this industrialization process reduces labor and which skills need to be improved in order to enable workers to remain on the job.

It is also recommended that the improvement of workforce skills in the short term be directed at mastering IT and digital technology. In the long term, the education curriculum should be directed at improving STEAM capabilities. Teaching and learning should use contextual methods that help students think critically, such as problem-based learning (PBL) and enquiry-based learning.

Educational and Labor Market Policies: Vietnam

First, education needs to stimulate and prepare learners to enter their work lives as well as provide methods that make it easier for them to access knowledge for future use. One appropriate approach is to strengthen STEM at the school level to equip students with knowledge along with practical applications. Learners can experience, explore, and discover technology associated with the knowledge learned from different teaching programs. Education and training should encourage creativity in science and technology to develop new technologies. PBL is an interdisciplinary approach to acquiring the knowledge and skills to solve problems. There are many advantages of PBL as it focuses on students, enabling active learning and better understanding and retention of knowledge; helps develop life skills that can be applied to many areas; and enhances content knowledge while promoting the development of communication, problem solving, critical thinking, cooperation, and self-directed learning skills. PBL can help students to function optimally using real-world experiences. By exploiting collective group intelligence, different perspectives can give different viewpoints on and solutions to problems.

Second, the Foreign Language Teaching and Learning Project was set up by the government for the period 2017–2025. It encourages the introduction of foreign language learning from kindergarten on and the teaching of many subjects like math and science in English at the university level. Moreover, online educational resources are used for all target groups.

Third, higher education institutions are always pioneers in the implementation of innovation, creativity, and starting a business. A startup support project is to be set up, requiring educational institutions to improve training and related assistance programs.

Fourth, the old thinking about education needs to be changed as higher education institutions take on new roles in lifelong learning as part of their mission in the new industrial age. The Ministry of Education and Training has designed the Scheme for Supporting Students' Startups and directs

educational institutions to renovate training programs by involving managers and employers as well as develop and publicize learning outcome standards. Moreover, universities support the coordination between higher education institutions and businesses by strengthening cooperation with businesses in order to link training with domestic and foreign labor market demand.

Higher education institutions now play active, creative, efficient, competitive, diverse education and training roles in the context of Industry 4.0. All these roles need to meet the demand for human resources in the new industrial age. The Ministry of Education and Training should amend and supplement some articles of the Higher Education Law for submission to the National Assembly for approval. The system of legal documents should be improved to adjust the implementation of the law after revision. The ministry has also submitted to the government a decree on university autonomy, replacing Resolution 77/ NQ-CP, formalizing autonomy as an inevitable path of higher education in Vietnam.

In terms of labor market policies, first, for promoting the development of the labor market, Vietnam must improve its legal framework consistent with market law; protect the legitimate interests of workers and employers; and create favorable conditions for workers to participate in the labor market, improve their qualifications, and meet market demand. The domestic and international labor markets should be linked, focused on forming a highly skilled labor force in the ASEAN region. The government should forecast labor supply and demand in the vocational education sector and improve the quality of vocational education. Vietnam's policymakers need to create a legal system to encourage innovation, associated with creating new jobs and supporting businesses to reduce retraining costs.

The government should encourage vocational schools to improve teaching methods and equipment as well as fund their transformation to Industry 4.0. It should organize training and redirection for workers made redundant by smart machines. In addition to professional skills, there are many other skills that need to be applied such as IT, communication, active listening, critical thinking, creative awareness, and problem solving. Enterprises need to create learning environments where workers can acquire skills in using new production technologies.

Vietnam is increasingly able to compete in global markets based on higher labor productivity and better working conditions. However, converting productivity growth into higher wages and better living standards requires effective labor market institutions, including the protection of workers' rights in different forms of employment, giving opportunities for collective bargaining for wages, improving the working environment, supporting labor union policies, and protecting workers in hazardous environments. Effective labor relations are the key to stability, productivity, and fairness, which will ensure sustainable, comprehensive development.

Social Partners
R&D, Innovation, and Industrial Policies: Indonesia
Entering the era of Industry 4.0, which demands changes especially in terms of employment, the partnership between industry and workers facilitated by the government and guided by the ILO is very important. The government, in Indonesia's case the Ministry of Manpower and Transmigration, must be a fair referee to foster cooperative relations between industry and APINDO (Indonesian Employers' Organization) and the three main trade unions, the KSPSI (All Indonesian Worker Union Confederation), KSBSI (Confederation of Indonesian Prosperity Labor Union), and KSPI (Indonesian Trade Union Confederation). The main issue is how to prepare for employment in the new era.

R&D, Innovation, and Industrial Policies: Vietnam

First, sectoral associations in Vietnam play an important role in fostering cooperation among members, protecting members' rights, and developing cooperative relations among associations. The associations discuss problems arising in business with senior managers and help to solve problems in manufacturing and exporting products.

Second, domestic enterprises need to focus on developing their science and technology bases. Enterprises should increase investment in research to create products with high economic value. They should upgrade and improve production systems accordingly.

Third, businesses need to promote exchanges of experience in product- and technology-related issues with partners. Enterprises need to organize and participate in technology exchange forums and science and technology fairs, both in the country and abroad, to exchange knowledge and gain access to advanced scientific applications. In particular, access to advanced scientific applications related to Industry 4.0 is the shortest path to business success.

Fourth, enterprises need to expand international cooperation to access new technologies from advanced countries. Enterprises need to exchange experience not only in science and technology but also in management.

Fifth, domestic enterprises should directly propose and participate in building a system of legal documents on science and technology, intellectual property rights, and competition law. The support of enterprises will help the government to issue a fitting system of laws to strengthen the development of science and technology related to Industry 4.0.

Sixth, SMEs in Vietnam need to link more closely with each other in the exchange and transfer of science and technology and their applications in production and business. SMEs play an important role in Vietnam's socioeconomic development not only in the present but also in the future. However, most still use outdated technologies or improve existing production lines without researching innovations. They need government help to play a more active role in technology absorption and innovation.

Educational and Labor Market Policies: Indonesia

The government along with its industry and social partners needs to anticipate the employment impact of the Fourth Industrial Revolution. These impacts include: 1) changes in the type of work and therefore changes in or adjustments to skills through training and education; 2) changes in work patterns and work relationships, thus requiring new labor law rules; and 3) overall changes in society, especially related to digital inequality, leading to uncertainties in employment which require a new social security system.

Educational and Labor Market Policies: Vietnam

Education needs drastic changes in the era of Industry 4.0. Currently, Vietnam's education is mainly traditional with passive learning. Therefore, it should be replaced by modern education in the form of online courses, virtual universities, e-learning opportunities, etc.

First, higher education should take advantage of global integration, reducing the lag of Vietnamese education compared with other countries. Teaching programs should update theory and practice annually. The content of programs and practical equipment should be modernized to suit future work.

Second, vocational schools need to connect directly with enterprises to understand labor market demand and the quality of labor training needed by businesses. Vocational schools need to invest in modern equipment so that learners can practice more instead of relying on mere theoretical learning. The linkages between vocational training institutions and enterprises should be stronger. Actions to strengthen linkages between vocational training institutions and enterprises include training courses for job requirements, retraining for employees or skilled workers, and job/worker standards for each industrial sector.

Third, professional associations should develop their own standards and then guide and collaborate with vocational schools, centers, and institutions to develop training programs to meet those standards.

Fourth, enterprises need to formulate training plans and update knowledge for employees annually. Enterprises should connect with educational institutions to make the most of available human resources. In particular, enterprises need to promote exchanges of research projects and request research projects applicable in their business spheres.

Fifth, sectoral associations can play important roles. They help members take full advantage of government programs funding R&D or education. They also advise the government on suitable approaches to support enterprises in R&D and education.

Recommendations for the Legacy Economies: India and the Philippines

Governments and Public Agencies
R&D, Innovation, and Industrial Policies: India
The biggest hurdle in the path of India's readiness for Industry 4.0 is a lack of innovation; a large number of innovations, specifically in rural India, are still unrecognized. Therefore, the following actions are recommended:

- Inclusion of innovation in course curricula in higher education, with at least one innovative idea and its recognition required to receive any degree or diploma.

- A mandatory percentage of the corporate social responsibility budget should be used to develop research facilities in institutions.

- Generous funding policies for research in the agriculture and product manufacturing sectors.

- Steps to enhance ECI rankings.

- Interaction between research needs and beneficiaries must be promoted through common portals and awareness programs.

- Emphasize company research and promotion to boost relational capital.

In addition, more R&D funding is needed for the aerospace, biotechnology, renewable energy, and automotive sectors.

R&D, Innovation, and Industrial Policies: The Philippines

No further detailed descriptions are possible because the national expert's report could not incorporate sufficient data.

Educational and Labor Market Policies: India

The following recommendations can be made for the educational policies of the Government of India:

- Raise teacher–student ratios in higher education.

- Promote outcome-based innovation and credit transfers.

- Industry should adapt and share problems directly at student forums.

- Make leapfrog changes in the syllabus.

- At least 40% of the syllabus should be interdisciplinary subjects to create permeability.

- Promote smooth transitions among science, humanities, and technical education.

- Promote cyberphysical education.

- Develop a sound training infrastructure for teachers.

- Set up a common teacher ability training and certification system, which should be compulsory before teachers are hired.

- Evaluate faculty development programs.

The Government of India has a huge challenge in managing and protecting the unorganized labor market. Embracing Industry 4.0 at the national level is certain to disrupt the labor market significantly. However, the effects will only be visible after a certain period of time. The following are a few recommendations for policies related to the labor market:

- Promote the delegation of authority and job autonomy in workplaces.

- Upgrade skills by bolstering second-chance policies.

- More of the workforce should be brought under the umbrella of the organized sector.

- Create common platforms for talent pools and employers.

- Campus recruitment should be replaced by nationwide talent acquisition.

- A leadership skill test for administrators should be compulsory.

Educational and Labor Market Policies: The Philippines

No further detailed descriptions are possible because the national expert's report could not incorporate sufficient data.

Social Partners

R&D, Innovation, and Industrial Policies: India

Recommendations regarding the role of social partners in R&D, innovation, and industrial policies include:

- Establishment of R&D and innovation centers across industrial sectors.

- Sharing product-based requirements with academic and vocational institutions.

- Regular assessment of the labor market and human capital.

- Promoting startups and skill centers in small cities deprived of standard employment.

R&D, Innovation, and Industrial Policies: The Philippines

No further detailed descriptions are possible because the national expert's report could not incorporate sufficient data.

Educational and Labor Market Policies: India

The social partners in India should play the following roles in educational and labor market policies:

- Private educational trusts should have integrated learning centers for skills pertaining to Industry 4.0.

- An outcome-based education system should be followed.

- Industries should be involved in the development of course curricula.

- Support should be given to for educational institutions in developing specific skills pertaining to Industry 4.0.

- Expedite future qualitative and quantitative skill requirements in advance to institutions.

- Ensure skill development after job loss.

Educational and Labor Market Policies: The Philippines

No further detailed descriptions are possible because the national expert's report could not incorporate sufficient data.

The Leading Economies: The Republic of China and Malaysia

Governments and Public Agencies

R&D, Innovation, and Industrial Policies: The Republic of China

1. R&D funding criteria for companies for high-value manufacturing, especially for Industry 4.0-related R&D programs, should:

   - Be guided by a long-term, e.g., 10-year, vision and roadmap.

   - Support innovative business models under an open, farsighted legal framework.

- Focus only on high value-added activities.

The current criterion of "high value-adding, cutting-edge industrial technologies," for example, will lead to too much emphasis on cutting-edge technologies and underestimate the importance of high value-adding technologies. In addition, without the guidance of a long-term goal, the ROC will always be a follower in some areas. Furthermore, lacking the support of a suitable legal framework, it is not very easy for the innovative business models encouraged in the current criteria to be outside the box.

2. Joint R&D programs for companies and research institutes/universities (for machine data analysis, cybersecurity, digital platforms, and digital talent) should be more open to each other. Companies should be able to join the R&D programs for institutes/universities and vice versa. As formal members, not simply subcontracted or consulting partners, program teams can then strategically integrate market insight, domain know-how, and advanced technologies into one project. The purposes are:

   - More effectively and efficiently solving the subtle, complicated issues of machine data.

   - Establishing the capability of cybersecurity and digital platforms in a more mission-oriented approach.

   - Facilitating the vocational training of digital talent through stronger university–industry and research institute–industry partnerships.

3. Funding support for participation in foreign national innovation programs (for competitive patents) should be provided. Open innovation is the only means for making good use of limited R&D resources and receiving more competitive patents, especially for Industry 4.0. In the ROC, however:

   - Only participating multilateral programs such as EU Horizon 2020 or contracted bilateral ones such as ROC–Germany joint R&D projects can obtain government funding support.

   - Not very close R&D and innovation cooperation, as implied by the index of "multistakeholder collaboration" (rank 23rd), causes reinvestment of limited R&D resources, domestically and internationally.

Wider, more systematic open innovation is therefore a direct, effective approach to cope with the above-mentioned issues. To promote this, funding support for encouraging participation in international innovation programs can be designed and focused on annually reviewed strategic domains, such as Industry 4.0 or 5G.

R&D, Innovation, and Industrial Policies: Malaysia
In strengthening the Industry 4.0 landscape, the Malaysian government is recommended to undertake the following:

1. Provide tax incentives for acquiring locally made/developed Industry 4.0 solutions. Organizations that acquire locally made or developed Industry 4.0 solutions (encompassing

consultation work, training, system design and architecture, integration of Industry 4.0 technology into operations) should be given tax incentives by the government as a way to boost the domestic Industry 4.0 ecosystem as well as to increase domestic value and knowledge creation. This could also positively impact intellectual property protection, leading to more patent applications.

2. Expand the MDEC's Global Online Workforce (GLOW) platform to include local Industry 4.0 solution providers. Beyond incentives, the government should expand the MDEC's GLOW platform to include a listing of competent local Industry 4.0 solution providers. The listing should be dynamic and based on a reputation economy model. This activity could also be tied to the readiness assessment program the government is currently running. Upon being assessed, organizations can be directed to the GLOW platform for engagement with solution providers. At present, the GLOW platform lists jobs from gig-economy platforms such as PeoplePerHour.com, DesignCrowd.com, freelancer.com, upworks.com, KerjaDigital, and freetimeworkz.

3. Transform competent local solution providers into remanufacturers. In Malaysia, remanufacturing is an industry that requires several key processes to be verified by the government to ensure that organizations claiming to perform remanufacturing carry out the required value-added activities. Currently, many competent local SMEs offer retrofitting of existing plant machinery into smart machinery. Although it is a cheaper alternative to buying new smart machines, retrofitting is still considered an inferior value-added activity as opposed to remanufacturing. At the very least, remanufactured products must go through OEM-level testing, and worn components must be replaced or restored to their original dimensions (via metal spraying, etc.). A structured transformation of competent local solution providers into remanufacturers would produce superior remanufactured machinery with smart manufacturing capabilities and would also raise the competitiveness level of local solution providers (remanufactured products could share the same HS code with new products).

4. Provide additional matching grant allocations for cyberphysical system (CPS)-related research: The matching grant allocation for the development of 5G network applications in the 2020 budget is a step in the right direction for Digital Malaysia, as it is expected that applications will benefit society more than industry. A dedicated matching grant allocation for the development of CPS leading to next-generation agile manufacturing systems, on the other hand, would be a boost in developing smart factory solutions and more in line with the Industry4WRD policy. Furthermore, by classifying it as a matching grant rather than an outright grant, the government could ensure the involvement of industry players in the research.

5. Provide matching grant allocations to develop locally made Industry 4.0 technology. Apart from promoting the use of locally made solutions, the government could further assist the growth of domestic value and knowledge creation by offering matching grants to local solution providers to develop Industry 4.0 technology such as additive manufacturing printers (metal and plastic) and collaborative robots. There are already local solution providers able to produce these technologies. With additional research grants from the government, the efforts of those solution providers could grow. The end goal of this activity is to produce a pool of local champions (each with its own patented technology) in each of the Industry 4.0 technology pillars.

Educational and Labor Market Policies: The Republic of China

A core recommendation for the ROC concerns an International Industry 4.0 Certification Program (for digital talent). To attract and nourish digital talent for Industry 4.0-related companies, national certification is helpful. The ROC's Industry 4.0-related national certification programs, such as those for automation or robotics, are not internationally recognized and thus will have limited effects on increasing employee salaries and encouraging capacity upgrades.

These issues will surely have negative effects on recruiting digital talent for Industry 4.0-related companies. To cope, cooperating with international partners' programs, such as the Siemens Mechatronic Systems Certification Program, is one of the most effective methods. An international Industry 4.0 certification program can then be planned, implemented, and promoted in a more systematic, internationalized way for related ROC industries to attract and nourish valuable digital talent.

Educational and Labor Market Policies: Malaysia

Tertiary education in Malaysia has recently undergone strategic reforms to better cope with the demands of Industry 4.0. Universities are restructuring their faculties to be multidisciplinary to meet the demands of education liberalization as well as Education 4.0, and the Malaysian TVET system is being streamlined. The following steps are recommended to the government to strengthen those exercises:

1. Provide allocations for graduates to attend Industry 4.0 "finishing schools." In order to complement formal tertiary education, the government is recommended to work together with Industry 4.0 solution providers as well as Industry 4.0 incubators (e.g., Co9P) to form a finishing school program. Participating solution providers must be compensated in terms of tax incentives. As for the program, suitable graduates from tertiary education will be sent to help work on projects for a maximum of six months with the solution providers, but unlike during internships, they are treated as graduates. Participating graduates will receive stipends from the government, and additional salary can be paid by the assigned solution provider (where the graduates are sent). In the end, not only will these graduates gain valuable experience in assisting real industrial projects (and in turn able to produce an impressive resume), they also could find a unique value proposition for themselves and set up their own technology startup companies. Funding should not be too challenging for these new startups as Malaysia has a number of venture capitalists.

2. Provide allocations for professional certification programs. As the strategy for solution providers is based on a reputation economy (via dynamic listing of historical performance), professional certification programs are needed to segregate competent professionals from the rest. Certification should be Industry 4.0 technology pillar based and emphasize system integration across all pillars. The body of knowledge for these certification programs must be in the spirit of the Industry4WRD policy, be industry driven, and have input from academia. As for graduates, related formal tertiary education programs should be paired with this certification.

3. Provide tax incentives for applications of responsible smart automation. At present, training to reskill and/or upskill employees is claimable under Malaysia's Human Resources Development Fund. This recommendation goes beyond that and it is proposed to prevent local employees from being replaced by automation. Therefore, organizations that integrate smart automation or any kind of significant Industry 4.0 technology without

letting go of local employees and that provide reskilling and/or upskilling to employees should receive tax incentives, as this would promote responsible integration of Industry 4.0 technology.

Social Partners

R&D, Innovation, and Industrial Policies: The Republic of China

1. Establish a cybersecurity alliance for Industry 4.0. To strengthen the Industry 4.0 ecosystem in the ROC, cybersecurity is one of the most important issues to be tackled. The investment in cybersecurity, however, usually cannot gain the expected return immediately or apparently. A cybersecurity alliance is one of the most effective ways to share the cost, reduce the risks, and increase the benefits. The proposed cybersecurity alliance could be established and operated through two means. The first is organizing companies, research institutes, and universities in a public–private partnership (PPP) mechanism to share knowledge and experience for reducing the cost and risks and to form special interest groups for polishing technologies and solutions through joint projects. The second means is forming a cybersecurity center of excellence under governmental, e.g., MOEA, and/or intergovernmental, e.g., APO, support to organize companies, research institutes, and universities for sharing and promoting best practices internationally and domestically in order to facilitate successful implementation of cybersecurity solutions.

2. Promote value chains for digital platforms. There are common languages, benefits, procedures, and, most importantly, domain know-how in an industry value chain. To ease the challenges of establishing digital platforms for Industry 4.0, such as cost and internal communication, value chain promotion should be more effective and efficient. Practical approaches to the promotion could involve the development of total solutions for digital platforms of strategic value chains through government R&D and innovation funding support. Each value chain should have its own total solution for the corresponding digital platforms, encouraging investment by all stakeholders. The strategic value chains should align with the key industries in the ROC's smart machinery national policy, including aerospace, machine tools, metal and transport, electronics and information, energy, 3C products, food, textiles, water hardware, and hand tools.

3. Form digital platform consulting teams. Innovative government demonstration site funding support should encourage the establishment and operation of digital platform consulting teams for the above-mentioned strategic value chains. Each value chain similarly should have its own consulting team for identifying the root causes of issues and then proposing effective approaches.

R&D, Innovation, and Industrial Policies: Malaysia

To increase the competitiveness of Malaysia in Industry 4.0, industries are recommended to:

1. Form consortia of solution providers. As Industry 4.0 requires systemic changes to an organization, it would be beneficial for local solution providers, especially SMEs and startups, to complement each other and work in consortia when engaging clients. This is recommended since it is an enormous task for a single company to offer holistic Industry 4.0 solutions and strategies to its clients. Furthermore, working in consortia enables end-to-end solutions to be delivered and specialization and in-depth expertise to develop.

2. Strategically adopt business intelligence and marketing intelligence. Adoption of Industry 4.0 by industry is critical in ensuring that Malaysia remains competitive in the future. However, Industry 4.0 goes beyond widespread automation and connectivity. Only by transforming their business models to adopt digitalization and integrate data analytics in decision making will industries unlock the true benefits of Industry 4.0. In order to achieve this, industries must change their mindset of not appreciating strategy and invest in the development of a practical, feasible transformation strategy that includes digitalization of processes and supply chains as well as provisions for preparing manpower and management to operate in an Industry 4.0 environment. Investment risks can be lowered by relying on the reputation economy when selecting consultants and/or trainers for this. This is where organizations such as the Federation of Malaysian Manufacturers and vendor/supplier associations such as the Proton Vendors Association (PVA) can play a key role in assessing consultants and trainers and provide their members with accurate recommendations.

3. Embrace research, innovation, and commercialization activities. Industries must embrace a research and innovation mindset to survive in a fast-changing digital world. For smaller organizations, it would be more feasible to pool resources and work with research institutes and/or universities in consortia working to address common industrial issues. Associations could also play a role in strategizing and managing research programs by coordinating projects, i.e., the Agile Manufacturing Program for the PVA with research projects on cell design, CPS integration, and smart logistics carried out by different consortia of SMEs.

4. Structure knowledge and best practices. Associations should also promote Industry 4.0 adoption best practices, guidelines (especially on technology adoption/transfer), and case studies by developing sector-specific industrial standards and ensuring that the standards are followed by their members. Development of industrial standards is a growing trend in Malaysia and is championed by SIRIM STS S/B, a subsidiary of SIRIM Berhad (formerly known as the Standard and Industrial Research Institute of Malaysia).

Educational and Labor Market Policies: The Republic of China

Establish a national Industry 4.0 training system for digital talent. Under long-term funding support from industry and/or government, an alliance of universities, research institutes, and companies should be established to collaboratively develop a national Industry 4.0 training system for both industry and academia. Furthermore, international benchmarking and cooperation, such as Siemens Cooperates with Education and SITRAN Training for Industry, should be strategically and continuously conducted for the short- and long-term success of the national Industry 4.0 training system. The purposes of the above-mentioned approaches are to: quickly and systematically nourish high-quality digital talent for Industry 4.0; ensure that the program meets the up-to-date needs of strategic industries; and prepare vocational and academic students for the future needs of strategic industries.

Educational and Labor Market Policies: Malaysia

In preparing the current and future workforce for Industry 4.0, industries in Malaysia are recommended to:

1. Support the finishing school program. Competent solution providers should play a role in assisting tertiary education graduates in honing their technical, scientific, and engineering skills by mentoring them in real projects and entrusting them with actual work beyond the tasks assigned

to interns. Furthermore, graduates with the right attitudes and performance could receive recommendations, ensuring that such an activity would grow into its own reputation economy.

2. Engage in digital social responsibility (DSR) programs. As the government has allocated tax incentives for companies engaging in DSR beginning from 2020 onward, the industry is recommended to take full advantage of those incentives and contribute to the community. This would in turn help to create a smart society as well as assist schools, colleges, and universities to receive much needed tangible and intangible assistance from industry. Industries can help educational institutes in their areas by sharing their experience in Industry 4.0, actively assisting in Industry 4.0-related educational activities, i.e., competition judging, and revising their syllabus and/or course contents.

3. Form unions and associations for gig workers. Industries in Malaysia are moving toward outsourcing back office and nonessential business functions to specialized gig workers. However, fees and other benefits are not regulated as there are no unions or associations that represent gig workers in Malaysia. Coming together to form function-specific associations and/or unions would help to stabilize professional fees and other contractual provisions.

Integrated Recommendations for All Six Economies

Governments and Public Agencies
R&D, Innovation, and Industrial Policies

In all economies, substantial investment in stationary and mobile ICT infrastructure is needed. In the nascent and legacy economies, the focus might be more on broad coverage of all, especially rural regions. In leading economies, the step forward to 5G networks needs to be carefully planned as a prerequisite for many Industry 4.0 applications.

All economies need some form of stimulation for R&D. For a broad incentive for industry to engage in more R&D, tax reduction programs may be useful.

For more specific issues and addressing technological challenges as described in the case of the ROC, dedicated funding programs will be more effective and efficient. Furthermore, for industry participation in these programs, a significant percentage, e.g., 50% or 60% of total project costs, of company funds can be required in a matched-fund or shared-budget approach. Thus, additional industrial investment can be leveraged.

For the systematic fostering of cooperative R&D among companies or between companies and academia, funding programs might be a more targeted approach. This cooperative R&D is essential for relational capital. All national experts recommend specific support for cooperative R&D. In the nascent and legacy economies, relational capital is already strong. Here, support for cooperative R&D could develop this strength. On the other hand, in the leading economies of the ROC and Malaysia, relational capital is rather weak (especially in Malaysia). Here, cooperative R&D can serve to mitigate that weakness.

Regarding knowledge domains, R&D support should reflect the structural conditions and needs of the respective economies. In leading economies like the ROC, the need is in the specific domains of advanced engineering and ICT technologies. In nascent or legacy economies, like India or the Philippines, ICT applications in agriculture may serve their development needs well.

An issue of importance for all economies is cybersecurity, another prerequisite for Industry 4.0. Cybersecurity should be addressed in R&D as well as educational policies. Furthermore, international activities, e.g., as moderated by the APO, might help to establish common standards.

In more general terms, international policy learning in R&D, innovation, education, and labor market policies with respect to preparedness for Industry 4.0 could be a very helpful activity of international and intergovernmental organizations like the APO. The APO's Centers of Excellence can serve as hubs for these activities.

Educational and Labor Market Policies

For all or almost all of the six economies, the following recommendations concerning the education system are made:

- Reform higher and vocational education, including the introduction of more effective, efficient learning methods like project-based learning or PBL and digital-learning environments.

- Provide closer links between education and industry and with other employers.

- Internationalize education and cooperate with international providers of education.

This internationalization of education seems especially relevant for the leading economies.

The demographic situation in most of the economies is characterized by a high percentage of young people, which naturally leads to a focus on initial vocational or higher education. Nevertheless, there will be more older members of the workforce in the future, and technological innovation cycles tend to become ever shorter. Both trends emphasize the necessity of giving more attention to continuing learning along the work life cycle, to be provided by vocational education and higher education institutions. The latter will be mostly responsible for educational subjects close to research, which holds for many issues in the Industry 4.0 context.

In setting educational and labor market policies, organizations like the APO might make extremely valuable contributions by organizing policy learning on an international or intergovernmental scale. In this aspect as well, the APO Centers of Excellence could serve as hubs for educational activities.

Social Partners

R&D, Innovation, and Industrial Policies

Social partners can play important roles in R&D and innovation policies. Industrial and employers' organizations can organize dialogues among their member companies to disseminate knowledge and experiences related to advanced technologies. They can also collect and structure their members' demands and suggestions regarding public R&D and innovation policies and communicate those suggestions to government. This is especially necessary for MSMEs, which may not have their own direct communication links with the government.

Trade unions can inform their members of coming changes and advise them regarding further education and training they might need to stay in the labor market. They can also communicate their members' needs to governments so that employees' voices can be heard and measures for socially just, fair innovation can be taken. This will also contribute to social peace and stability.

On an international or intergovernmental scale, organizations like the APO can invite governments and sectoral social partner organizations to discuss and develop policies and standards tuned to the needs of specific sectors.

Educational and Labor Market Policies

Social partners may use their own educational institutions to inform their members of upcoming changes or set up new education programs to do so. Most importantly, social partner organizations can help government and other public organizations in the education sector to align their programs more closely with the requirements in the world of work. They can help to set or adjust curricula and provide professional standards to guide the development of curricula.

ANNEX A
FULL LIST OF INDICATORS

1. Contextual Conditions

a. Economy

- Global Economic Indicators

  • Medium high-tech and high-tech industries (in % of manufacturing value added)

  • Manufacturing value added in the economy (in % of GDP)

  • Manufacturing value added (in USD)

  • Market size

- Economic Indicators Specific to Industry 4.0

  • ICT-enabled business models

  • Firm-level technology absorption

  • Company investment in emerging technology

  • Companies embracing disruptive ideas

b. R&D

  • R&D expenditures

  • Scientific and technical publications

  • Patent applications

  • Multistakeholder collaboration

c. Education

- Global Educational Indicators

  • Mean years of schooling (retrospective)

  • Quality of universities

  • Quality of math and science education

- Quality of vocational training

- School life expectancy (prospective)

- Pupil-to-teacher ratio in primary education

- Critical thinking in teaching

- On-the-job training

  ○ Educational Indicators Specific to Industry 4.0

  - Availability of scientists and engineers

  - Digital skills among population

d. Labor Market

- Manufacturing employment

- Knowledge-intensive employment

- National capacity to attract and retain talent

- Active labor policies

e. Digital Infrastructure

- Mobile-cellular telephone subscriptions

- LTE mobile network coverage

- Internet users

- Fixed-broadband Internet subscriptions

- Internet bandwidth

- Mobile-broadband subscriptions

f. Policies

- Cybersecurity commitment

- Government procurement of advanced technology

- Future orientation of government

2. Innovation Capability

a. Human Capital

- Mean years of schooling (retrospective)

- Quality of universities

- Quality of math and science education

- Quality of vocational training

- School life expectancy (prospective)

- Pupil-to-teacher ratio in primary education

- Critical thinking in teaching

- On-the-job training

- Availability of scientists and engineers

- Digital skills among population

b. Complexity Capital

- Economic Complexity Index (ECI)

c. Structural Capital

- Willingness to delegate authority

- Capacity for innovation

- Collaboration and sharing of ideas within company

d. Relational Capital

- Collaboration among companies in sharing ideas and innovating

- Collaboration between business and universities on R&D

- Capacity for innovation

- Collaboration and sharing of ideas within companies

ESTIMATIONS OF REPUBLIC OF CHINA SCORES

GLOBAL ECONOMIC INDICATORS (MANUFACTURING).

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
Medium high-tech & high-tech industries (% of mfg. value added)	61.9	77.4	USA (buyer sophistication, WEF 2018)	0.799742
Manufacturing value added in economy (% of GDP)	30.75	32.1	PR China (%, FoP and DGBAS of ROC)	0.957944
Manufacturing value added (USD)	171.124	2.999.885	PR China (M USD, FoP, and DGBAS of ROC)	0.057044
Market size	66	100	PR China (value, FoP, and WEF)	0.66
Average ratio, global economic indicators (manufacturing)				0.618682

ECONOMIC INDICATORS SPECIFIC TO INDUSTRY 4.0.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
2.05 Firm-level technology absorption	5.2	6.0	Sweden (WEF 2017–2018)	0.866667
2.06 Impact of ICT on new services and products	5.3	5.9	Finland (WEF The Global Information Technology Report 2016)	0.898305
2.09 Company investment in emerging technology	100	100	Israel (WEF 2018, National Development Council, ROC, 2018) In the ROC, private R&D expenses are higher than public ones, as shown in the following figure	1
2.11 Companies embracing disruptive ideas	4.2	5.7	USA (WEF 2018)	0.736842
Average ratio, economic indicators specific to Industry 4.0				0.875453
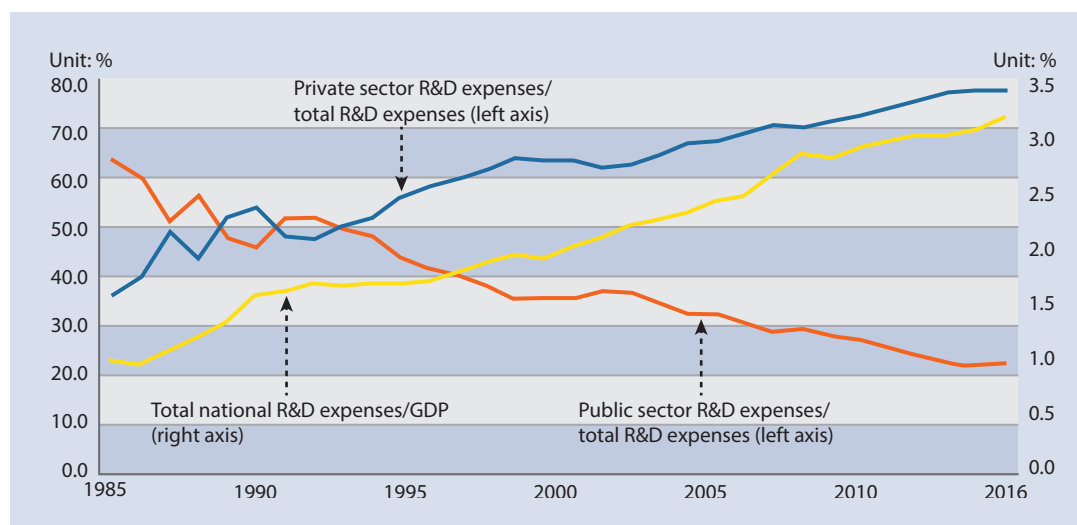
GLOBAL EDUCATIONAL INDICATORS.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
3.04 Mean years of schooling	12.1	14.2	Finland (WEF 2018, value)	0.852112676
3.10 Quality of math and science education	5.2	6.5	Singapore (WEF 2017–2018, value)	0.8
3.11 Quality of vocational training	4.6	6.5	Switzerland (WEF 2018, value)	0.707692308
3.12 School life expectancy	16.6	22.9	Australia (WEF 2018, value)	0.72489083
3.13 Pupil-to-teacher ratio in primary education	87.3	100.0	Luxembourg (WEF 2018, score)	0.873
3.14 Critical thinking in teaching	4.2	5.7	USA (WEF 2018, value)	0.736842105
GCI 12.08 Research institutions prominence index	47.5	100.0	USA (WEF 2018, quality of research institutions)	0.475
3.16 On-the-job training	4.95	6.2	Switzerland (FoP 2018, WEF 2016–2017, value)	0.798387097
Average ratio, global educational indicators				0.745990627

EDUCATIONAL INDICATORS SPECIFIC TO INDUSTRY 4.0.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
3.06 Digital skills among population	5.1	5.8	Sweden (WEF 2018, value)	0.879310345
3.05 Availability of scientists and engineers	4.7	6.0	Finland (WEF 2017–2018, value)	0.783333333
Average ratio, educational indicators specific for Industry 4.0				0.831321839

LABOR MARKET INDICATORS.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
3.01 Manufacturing employment	26.9	27.3	Czech Republic (FoP 2018, DGBAS of Executive Yuan of ROC)	0.985348
3.02 Knowledge-intensive employment	31.8	54.3	Singapore (FoP 2018, WEF The Global Information Technology Report 2016)	0.585635
3.08 National capacity to attract and retain talent	3.8	6.1	Switzerland (FoP 2018, WEF 2016–2017)	0.622951
3.15 Active labor market policies	4.3	5.8	Switzerland (WEF 2018)	0.741379
Average ratio, labor market indicators				0.733828

DIGITAL INFRASTRUCTURE INDICATORS.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
2.01 Mobile-cellular telephone subscriptions (/100 pop.)	121.8	249	Hong Kong SAR (WEF 2018, value)	0.489156627
2.02 LTE mobile network coverage	99	100	Bahrain (FoP 2018, value, OpenSignal 2016)	0.99
2.03 Internet users	79.7	98.2	Iceland (WEF 2018, value)	0.811608961
9.05 Fixed-broadband Internet subscriptions	24,2	45.4	Switzerland (WEF 2018, value)	0.533039648
9.06 Internet bandwidth	717.6	8397.9	Luxembourg (WEF 2017–2018, value)	0.085449934
9.07 Mobile-broadband subscriptions	99.9	243.4	United Arab Emirates (WEF 2018, value)	0.410435497
Average ratio, digital infrastructure indicators				0.553281778

POLICY/GOVERNANCE INDICATORS.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
2.07 Cybersecurity commitment	0.8	0.9	Singapore (FoP 2018, value; IMD World Digital Competitiveness Ranking 2018, ranking)	0.888889
2.10 Government procurement of advanced technology products	3.8	5.5	United Arab Emirates (FoP 2018, value; WEF 2016–2017, ranking)	0.690909
5.03 Future orientation of government	3.7	6.1	Singapore (WEF 2018, value)	0.606557
Average ratio, policy/ governance indicators				0.728785

HUMAN CAPITAL INDICATORS.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
3.04 Mean years of schooling	12.1	14.2	Finland (WEF 2018, value)	0.852112676
3.05 Availability of scientists and engineers	4.7	6.0	Finland (WEF 2017–2018, value)	0.783333333
3.06 Digital skills among population	5.1	5.8	Sweden (WEF 2018, value)	0.879310345
3.09 Quality of universities	17.0	159.0	USA (FoP 2018, value; QS 2017, ranking)	0.106918239
3.10 Quality of math and science education	5.2	6.5	Singapore (WEF 2017–2018, value)	0.8
3.11 Quality of vocational training	4.6	6.5	Switzerland (WEF 2018, value)	0.707692308
3.12 School life expectancy	16.6	22.9	Australia (WEF 2018, value)	0.72489083
3.13 Pupil-to-teacher ratio in primary education	87.3	100.0	Luxembourg (WEF 2018, score)	0.873
3.14 Critical thinking in teaching	4.2	5.7	USA (WEF 2018, value)	0.736842105
3.16 On-the-job training	4.95	6.2	Switzerland (FoP 2018, value; WEF 2016–2017, ranking)	0.798387097
Average ratio, human capital				0.726248693

COMPLEXITY CAPITAL: ESTIMATION OF THE ROC'S SCORE AS AN AVERAGE OF "ADVANCED" APO MEMBER ECONOMIES.

Country	Raw score	Normalized score (Japan = 100)
Japan	2.30	1.00
Singapore	1.50	0.65
ROK	1.80	0.78
Malaysia	0.80	0.35
Average	1.60	0.70

STRUCTURAL CAPITAL INDICATORS.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
GCI 11.09 Willingness to delegate authority (1–7)	4.8	6.1	Denmark (WEF 2018, value)	0.786885
GCI Capacity for innovation	5.1	6.2	Switzerland (WEF 2017–2018, value)	0.822581
Collaboration inside company (1–7)	4.8	5.8	Switzerland (WEF 2018, value; In your country, to what extent do people collaborate and share ideas within a company? = 1–7)	0.827586
Average ratio, structural capital				0.812351

RELATIONAL CAPITAL INDICATORS.

Item	ROC	Best	Remarks: best country (source, unit)	Ratio
Multistakeholder collaboration (1–7)	4.7	5.8	USA (WEF 2018, value)	0.810345
Collaboration between companies (1–7)	4.6	5.7	USA (WEF 2018, value; In your country, to what extent do companies collaborate in sharing ideas and innovating? = 1–7)	0.807018
University–industry collaboration in R&D (1–7)	4.8	5.9	USA (WEF 2018, value; In your country, to what extent do business and universities collaborate on R&D? = 1–7)	0.813559
Average ratio, relational capital				0.810307

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Bangladesh

Cambodia

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Japan

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Nepal

Pakistan

Philippines

Singapore

Sri Lanka

Thailand

Turkey

Vietnam