Background Paper
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Building the Capacity to Adapt, Adopt, Deploy, and Use Frontier Technologies in Low Income Countries

I. The Challenge and Promise of Frontier Technologies

There is a fear that the widespread adoption of frontier technologies– AI, robotics, 3D printing, machine learning, virtual reality (VR), augmented reality (AR), remote sensing, predictive software, cloud computing, and the internet of things (IoT) – in developed countries will reduce the labor-cost competitiveness of today's less industrialized economies in Asia and Africa, increase the technological gap between them and developed countries, and make it more difficult for these less industrialized countries to catch up, diversify their economies, and create jobs. However, the emergence of frontier technologies does not have to be a harbinger of hardship for developing countries. These same frontier technologies that are causing so much fear and trepidation can also be a source of jobs, economic development, rising living standards and structural transformation. But to exploit these opportunities, developing countries, supported by international development partners, must build the capacity to scale up the deployment of these technologies for the SDGs and incorporate them into the local production of food, manufactured goods, and services for both rapidly growing regional markets as well as global value chains. This is a daunting, but achievable, task.

In the past, countries like China, Mexico, Brazil, the High Performing Asian Economies[1] moved up the income ladder by transferring labor and capital from relatively lower-productivity agriculture to higher productivity manufacturing and services. Within manufacturing, the so-called flying geese model[2] took over. Developing countries started at the bottom rung of the manufacturing ladder, specializing in low-skill, low wage, low-value added assembly operations for more technologically adept multinational corporations. But over time, some developing countries managed to move up the value chain by replacing low wage, low skill manufacturing activities with higher skill, higher value-added activities.

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[1] The World Bank in 1993 classified Japan, Hong Kong, Thc Republic of Korea, Singapore, Taiwan, China, Indonesia, Malaysia, and Thailand as High performing Asian Economies (HPEAs). See Birdsall,Nancy M.; Campos,Jose Edgardo L.; Kim,Chang-Shik; Corden, W. Max; MacDonald, Lawrence [editor]; Pack,Howard; Page,John; Sabor, Richard; Stiglitz,Joseph E..1993. *The East Asian miracle : economic growth and public policy : Main report (English).* A World Bank policy research report Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/975081468244550798/Main-report

[2] Lin, Justin Yifu, From Flying Geese to Leading Dragons: New Opportunities and Strategies for Structural Transformation in Developing Countries (June 1, 2011). World Bank Policy Research Working Paper No. 5702, Available at SSRN: https://ssrn.com/abstract=1871599

They did so by designing and implementing programs explicitly designed to improve the skill level of the labor force, augment the nation's science, technical, and engineering capacity, and help local companies gain the experience, know-how, and capacity to organize, manage and carry out more sophisticated tasks requiring higher skilled labor and more sophisticated technology.[3] Meanwhile, recent newcomers to the development process picked up the low-skill activities that the more advanced developing countries had outgrown. With appropriate policies, they too hoped to close the skills and technology gap and eventually move up the value chain. But there was nothing automatic or mechanistic about these processes of structural transformation and economic catch-up. The minimum pre-requisites were smart policies to promote technology learning, competent implementation of those policies, and companies with the organizational and institutional capacity to apply that hard-won technological know-how to producing globally and regionally competitive goods and services.

The fear now is that frontier technologies and the so-called Fourth Industrial Revolution[4] will upend these traditional development processes, making what was always a difficult journey even more daunting. Frontier technologies are undoubtedly disrupting traditional development processes as low wage, repetitive tasks as well as such higher skilled jobs such as radiologists and legal researchers increasingly become the domain of robots, AI, machine learning, and automation. In principle, these technological developments have the potential to create an unbridgeable income and technology achievement gap between developed and developing countries, making it more difficult for low income countries to progress and leaving millions of developing country workers with no escape from grinding poverty.

Fears about the potentially adverse impacts of new technology pre-date the emergence of frontier technologies by at least five centuries, as Calestous Juma observed in *Innovation and Its Enemies: Why People Resist New Technologies*[5]. While it is important to address these fears head-on, the dangers posed by frontier technologies to LDC and low-income country development models need to be put in context, for the following reasons:

- LDCs were not technologically proficient before the advent of frontier technologies and they did not stumble and fall behind once frontier technologies become more prominent. On the contrary, most had not mastered the previous generations of technology that were in widespread use in wealthier developing countries for improving access to off-grid electricity, potable water, waste to energy, etc. If developing countries can formulate national capacity building deployment strategies for adapting, adopting, and using frontier technologies[6], they may, in fact, be able to leapfrog traditional development models and accelerate development.

[3] This process, known as "moving up the value chain" entails two related steps. First, a country shifts from producing low-cost, low-skill intensive goods and services to more technologically sophisticated goods and services. But second, and more importantly, companies within that country move beyond simple manufacturing and assembly operations, including the assembly of high tech sophisticated products like smart phones and computers, to higher value added processes such as design, process engineering, and marketing, among others. For details, see World Bank. 2011. *Moving Up the Value Chain: A Study of Malaysia's Solar and Medical Device Industries.* Washington, DC. © World Bank. *https://openknowledge.worldbank.org/handle/10986/12572*

[4] Klaus Schwab, The Fourth Industrial Revolution, World Economic Forum, 2016

[5] Calestous Juma, Innovation and Its Enemies: Why People Resist New Technologies, Oxford University Press, 2016.

[6] The Background Note for Chapter 2 as well as the final section of this Background Note discuss some of the obstacles inhibiting the deployment of frontier technologies in developing countries as well as policies for

- Africa and other regions may be able to replace traditional manufacturing with non-manufacturing activities -- dubbed" industries without smokestacks." These include "agro-industry and horticulture, tourism, some business services—including ICT-based services—and transport and logistics."[7] However, industries without smokestacks will not be a refuge from technological progress. On the contrary, frontier technologies are likely to play as prominent a role in industries without smokestacks as in more traditional sectors.
- The pace of technological progress is not going to slow down just because LDCs are at risk of falling behind. If poor countries are falling behind because they are not able to deploy and exploit frontier technologies, the only pragmatic option is to remove the obstacles to deployment and build the capacity to catch-up.
- The same fears expressed about frontier technologies could have been expressed ages ago about the advent of fire and stone tools, the frontier technologies of their day – e.g., early adopters will gain an advantage, leaving late adopters behind and creating inequality; these technologies can be used to improve people's quality of life as well as well as for war, conquest, murder, and pillage. But at the end of the day, frontier technologies are neither inherently good nor bad. As with fire and stone tools, what matters most is how they are used.
- A recent World Bank report notes[8] that the low wage assembly jobs that are most in danger of being destroyed by frontier technologies do not currently exist to any great extent in the poorest countries where indigenous manufacturing accounts for a below average share of both GDP and formal sector employment. Consequently, although robots may abort the growth of new jobs that do not currently exist, the threat of replacing existing jobs with robots is not as significant as it may be in developing countries that are currently more reliant on low wage manufacturing.

II. The Opportunities for Exploiting Frontier Technologies for Development

For developing countries, the critical issue is whether they can adapt, adopt, and use frontier to forge a new development model for wealth creation and sustainable development that leaves no one behind. The challenges and opportunities are both daunting and boundless. For example:

Smart Cities. Africa is projected to have 24 million more people living in cities each year between now and 2045. This is the equivalent of building approximately three New York Cities every year for the next 25 years. Providing potable water, power, sanitation, health care, transportation, and food to the current underserved urban populations as well as to the hundreds of millions of new residents that are expected to populate new urban settlements can either be viewed as an insurmountable problem or a new opportunity for innovation, growth, jobs and wealth creation. Frontier technologies can play an important role in

surmounting these obstacles. A detailed discussion of these obstacles is also available in United Nations Conference on Trade and Development, The Least Developed Countries Report 2010: Towards a New International Development Architecture for LDCs, available at: https://unctad.org/en/Docs/ldc2010_en.pdf and United Nations Conference on Trade and Development, The Least Developed Countries Report 2007: Knowledge, Technological Learning and Innovation for Development, available at: https://unctad.org/en/Docs/ldc2007_en.pdf

[7] Page 3, https://www.brookings.edu/research/exploring-new-sources-of-large-scale-job-creation-the-potential-role-of-industries-without-smokestacks/?utm_campaign=Africa

[8] Choi, Jieun, Mark A. Dutz, and Zainab Usman, eds. 2020. *The Future of Work in Africa: Harnessing the Potential of Digital Technologies for All*. Africa Development Forum. Washington, DC: World Bank.

designing and building livable, sustainable urban communities in developing countries if government, business, international development partners, and civil society learn how to put them to use.

Smart Agriculture. Feeding this rapidly growing urban population is another daunting challenge and potential opportunity for employment creation and national development. The solution will entail linking rural, peri-urban, and urban communities in an urban food ecosystem encompassing (i) sustainable urban intensification; (ii) post-harvest storage and processing; (iii) transportation; and (iv) distribution to end customers. None of this will be possible on a scale commensurate with the size of the urban food challenge without harnessing a wide range of frontier technologies including connectivity (ICT, IoT, mobile money, fintech financial services); controlled environmental agriculture including vertical farming and horticulture; block chain; high quality enhanced seed; enhanced genetics including cloud biology; nanotechnology and advanced materials; and 3D printing of cells, food, machinery and structures.[9]

Smart Factories. Smart factories which combine AI, machine learning, Open Source software, robotics, 3D printing, cloud computing, and big data analytics are becoming a more prominent feature of the manufacturing landscape. The term "smart factory" entails

> "an integration of shop floor decisions and insights with the rest of the supply chain and broader enterprise through an interconnected IT/OT landscape. This can fundamentally change production processes and enhance relationships with suppliers and customers…. [S]mart factories go beyond simple automation. The smart factory is a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes. Smart factories can operate within the four walls of the factory, but they can also connect to a global network of similar production systems, and even to the digital supply network more broadly." [10]

At present, most smart factories are located primarily in developed countries, but automobile related smart factories are also springing up in Mexico, Vietnam, Thailand, and Indonesia. [11] In addition, Rwanda, Ghana, South Africa, and Nigeria as well as countries in other regions may also be well-positioned to capture some of the jobs and economic growth spawned by smart factories. That will enable them to pole vault over the low-wage, assembly operation stage of development which, in any event, will no longer exist to the same extent as in the past. These smart factories and their related smart supply chains could serve as regional and local growth poles if the countries position themselves to capture these benefits.

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[9] For a more detailed and comprehensive overview of these frontier technology opportunities see, Fred Davies and Banning Garrett, Connecting Farm, City, and Technology to Transform Urban Food Ecosystems for the Developing World, Global Federation of Competitiveness Councils, 2019. Available at: https://docs.wixstatic.com/ugd/f344ed_2a423f9a4453415f91c8ec944a2a1af3.pdf

[10] Rick Burke , Adam Mussomeli , Stephen Laaper , Martin Hartigan , Brenna Sniderman, The smart factory Responsive, adaptive, connected manufacturing, Deloitte University Press, P. 5. Available at: https://www2.deloitte.com/content/dam/insights/us/articles/4051_The-smart-factory/DUP_The-smart-factory.pdf

[11] Much of this discussion is drawn from, Robert B. Cohen, Disruptive Technology, Smart Factories and Economic Development, July 2020. Available on the Global Solutions Summit website at: http://www.globalsolutionssummit.com/uploads/3/1/5/5/31554571/cohen_--_gss_blog_--_final.pdf

The ripple effects of smart factories will extend to second and third tier suppliers in countries that are not home to smart factories and impact sectors that are not generally viewed as technological leaders. For example, the Wilson Center, a Washington, DC-based think tank, cites the hypothetical example of a toy store in Canada that places an order for stuffed animals with a US-based toy manufacturer which, in turn, orders components for stuffed animals from factories in Mexico.[12] But this seemingly simple, low-tech supply chain is organized, managed and coordinated via sensors connected to a low-latency internet of things, a private cloud, machine learning, robots, and AI algorithms.

As this example suggests, even in the supposedly low-tech toy sector, dumb suppliers and dumb factories will find it difficult to co-exist in the same supply chain with smart factories and smart suppliers. To thrive in a world of smart factories, second and third tier supplier must be able to receive and transmit up-to-the second data via the cloud and, more importantly, instantaneously adjust design, production, performance characteristics, and other activities. In the wake of these requirements, countries and companies that previously relied on seemingly inexhaustible supplies of low-wage, unskilled labor will discover that they must get smarter to survive. At a minimum, this will entail upskilling personnel and adapting machinery to support high speed information flow and IoT connectivity. It will also require high speed internet connectivity and access to secure cloud computing platforms.[13]

III. The Way Forward: Learning to Get Smart

In the face of this technological revolution and the advent of smart cities, smart agriculture, and smart factories, learning how to get smart and deploy frontier technology will be indispensable. Relying on older technology will be a recipe for falling further behind. At present, however, developing countries are threatened not so much by frontier technology as by a yawning deficit of institutional capacity to exploit a "latecomer" strategy[14] for adopting, adapting, and using that technology in traditional sectors as well as for diversifying into new, more dynamic sectors. Any company can buy a 3-D printer. Very few companies can integrate those 3-D printers into their production process to produce a globally or regionally competitive good and service while also staying abreast of fast-moving technological trends and organizing and managing a wide-ranging network of suppliers, customers, skill development programs, etc.[15] At a bare minimum, to succeed in this arena, companies need to be able to (i) determine what they need to know but don't know; (ii) learn what they don't know; and most importantly, (iii) stay abreast of a rapidly changing technology landscape. Catching up is a continuous, ongoing process, not a one-time phenomenon.

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[12] Wilson Center, 5G Beyond Borders, available at: https://www.wilsoncenter.org/sites/default/files/interactives/64545/index.html?emci=e72252e4-88cb-ea11-9b05-00155d03bda0&emdi=0cfbb567-34cc-ea11-9b05-00155d03bda0&ceid=20390

[13] Anielle Guedes, Industry 4.0 Approaches and Considerations for Development, unpublished memo.

[14] John A. Mathews, "Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-Up Strategies," **Asia Pacific Journal of Management**, 19, 467–488, 2002

[15] The case of CyBe, a Netherlands-based 3D printing company active in the construction 3D printing sector is instructive. Technically, CyBe sells a variety of 3D printers for the construction industry. But the firm employs architects, engineers, and urban planners to provide the 3D files to the 3D printing team. It purchases robot arms, an integral part of the 3D printer, from ABB and software from another specialized vendor.

How can countries and companies embark on this learning journey? Several initiatives might provide a useful starting point.

The STI dialogue should shine a renewed spotlight on policies for promoting technology catch-up, adoption, and deployment. This consciousness raising dialogue could start by exploring historical lessons of experience, examining what various countries did right and wrong in terms of technology catch-up, how firms and workers acquired the requisite skills and experience to move up the value chain, and how today's developing countries can adapt these lessons of experience to a world increasingly dominated by frontier technologies and regional trade blocs. Many lessons of experience will undoubtedly draw from Asia's experience with the mass production of electronics, but other relevant examples might include experiences with medical devices and the solar industry as well as software, viticulture, fish farming, and higher value agriculture.[16]

Relevant questions might include the following: Are there the sector-specific lessons? What are the broader more general cross-sectoral lessons of experience and pre-requisites for success? And most importantly, which lessons are salient in a world dominated by frontier technologies and changing global trade dynamics. Related to this last point, the dialogue should explore the possibility of developing continental value chains focused on continental development priorities including the application of frontier technologies to such sectors as transportation and logistics, fintech, potable water and sanitation, waste to energy, smart cities, affordable housing, and low-cost, and high quality health care among others. These continental value chain programs could be supported by regional trading arrangements such as the Africa Continental Free Trade Area, local and continental procurement programs, and financing mechanisms involving local and regional sovereign wealth funds, pension funds, institutional investors, and guarantee instruments.

UNCTAD's Framework for Science, Technology, and Innovation Policy (STIP) Reviews can play a vital role. It can unite national governments, civil society stakeholders, and international development partners around a framework for catch-up strategies that harness frontier technologies for smarter, more sustainable cities, food security and smart agriculture, and employment generation in smarter factories. Many of the specific policies and programs outlined in the recommendation section of the Chapter 2 Background Note, especially the discussion of USA Manufacturing Institutes, would be relevant here as well.

[16] For examples of relevant case studies see Moving Up the Value Chain in Malaysia's Medical Device and Solar Industries (with Philip Schellekens, Alfred Watkins, Travis Bradford and Mario Gobo). Technical Assistance report prepared for the Economic Planning Unit in the Prime Minister's Office. (July 2011). https://openknowledge.worldbank.org/bitstream/handle/10986/12572/694920WP00PUBL0ovingUpTheValueChain.pdf?sequence=1 and also Vandana Chandra (ed.), Technology, Adaptation and Exports: How Some Developing Countries Got It Right, World Bank, 2006 available at https://openknowledge.worldbank.org/bitstream/handle/10986/7118/368000PAPER0Te1R0OFFICIAL0USE0ONLY1.pdf?sequence=1&isAllowed=y

Preparing for smart factories deserves special attention.[17] First and foremost, smart factories rely on high speed internet and cloud services. Success in the smart factory arena will be impossible if these essential services are not available at world class standards and integrated into a broader digital ecosystem. Second, the digital ecosystem should include shorter term training courses and longer-term apprenticeship programs to equip workers with the specific skills to thrive in smart workplaces. Technical universities and technical colleges should deliver these training programs, in close collaboration with smart factories themselves. National governments should be prepared to defray a substantial portion of these training costs, especially in the initial period. Third, national governments will need to make a special effort to attract smart factories and implement supplier development programs to prepare a local cadre of smart suppliers to support these smart factories. Learning how Mexico, Vietnam, Indonesia, and Thailand as well as more developed countries such as Korea[18] accomplished each of these tasks in partnership with local stakeholders and foreign investors will be especially relevant. Fourth, governments, civil society and local stakeholders will need to implement these smart factory programs alongside parallel programs to deploy frontier technologies for the SDGs. Ideally, these parallel tracks should reinforce and complement each other.

These challenges are daunting, but the payoff from successful implementation are likely to be enormous.

[17] For further details of these policy issues and options see Cohen, ibid., available at http://www.globalsolutionssummit.com/uploads/3/1/5/5/31554571/cohen_--_gss_blog_--_final.pdf

[18] A summary of the Korean experience with smart factories can be found in UNCTAD, "Enhancing Productive Capacity through Services: Note by the UNCTAD Secretariat," Trade and Development Board, Trade and Development Commission, Multi-year Expert Meeting on Trade, Services and Development, Seventh session, Geneva, 1–2 May 2019 Item 3 of the provisional agenda, available at https://unctad.org/meetings/en/SessionalDocuments/c1mem4d20_en.pdf