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Could Innovation and Productivity Drive Growth in African Countries? Lessons from Korea

Shahid Yusuf

Abstract

The Korean model of development that flowered in the final third of the twentieth century remains a fertile source of lessons for countries in sub-Saharan Africa attempting to achieve sustainably high rates of growth. Korea relied on two principal drivers. One was a high level of investment in manufacturing activities and infrastructure and a second was steady gains in factor productivity aided first by rapid technology assimilation and complemented in the 1980s and 1990s by own research and innovation. Because gross capital formation in African economies is likely to stabilize at levels well below those attained by Korea, and the services sector accounts for a larger share of African GDP, factor productivity will need to contribute more to growth than investment. For that reason, Korea's nurturing of science, technology, and innovation capabilities, which has helped stimulate productivity, can be a source of lessons. The purpose of this paper is to underscore the role of productivity, to show how Korea built the technological capabilities underpinning productivity gains, and to extract relevant pointers for African countries that will depend more on services than on manufactures to propel their development and exports.

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Introduction

Throughout the last quarter of the twentieth century and into the first decade of the 21st century, the canonical model favored by most countries was rooted in structural change that created an industrialized economy, a source of jobs and the basis of prosperity. The drivers of this structural change and associated growth were capital accumulation and the transfer of workers from agriculture to the urban-industrial economy (van Neuss 2019). Demand pull complementing factor supply push was sourced from domestic consumption and exports.[1] The standard recipe for rapid growth was the building of manufacturing capacity through large infusions of capital—domestic and foreign—and the channeling of an increasing fraction of industrial production into exports.

Policymakers across the world, took this simple recipe to heart and industry cum export led growth became the default strategy for many developing economies.[2] It is a strategy that enabled a few East Asian and Eastern European countries to enter the ranks of upper middle- and high-income economies.

Over the past two decades, a new development paradigm has begun taking shape and its implications for policy are far-reaching. In this paradigm, the traditional sources of growth—physical capital and labor—share the center stage with science, technology, and innovation (ST&I) and a skilled workforce, which together with newer vintages of capital, can help raise productivity and per capita incomes.[3] Structural change concomitant with development is seen as giving rise to a system in which services are as critical as industry with the likelihood that the diffusion of digital technology could enlarge the economic space occupied by higher value adding services, including through the continuing servitization of manufacturing (Yusuf 2015).[4]

The paper is divided into four sections. As the development process evolves, the new stylized facts coming to the fore are examined in section 1. These include the diminished share of manufacturing in GDP and the increasing importance of total factor productivity as a driver of growth. Section 2 discusses the need for late starting African economies with rudimentary ST&I systems to make haste and close the gaps in research capacity and productivity. Section 3 shows how they can draw guidance and inspiration from Korea's creation of an innovation system over a half century with qualifications, as Korea focused on industrialization and structural change in African countries now favors services as does digital technology. From this experience, some relevant and some not,

1 Mijiyawa (2017) identifies the following determinants of manufacturing activity in SSA: size of domestic market; good governance; and exchange rate depreciation.
2 Although several African countries attempted to implement the export-led strategy, none have managed to pull it off. McMillan et al (2017).
3 Total factor productivity has been on the growth radar ever since Robert Solow's research in the mid 1950s found a large residual that could not be accounted for by factor inputs. Subsequent research has shown that RD&I are among the major contributors to the residual. Abramovitz (1993); Griliches (1996); Jones (2022); Jones (2016).
4 The potential of services led growth is explored at length by Nayyar, Hallward-Driemeier and Davies (2021); Cozet and E. Milet (2015); Baines et al. (2009).

section 4 presents six lessons pertinent for economies in SSA lessons, which could enable them to acquire usable technologies and enhance indigenous innovation capabilities.

1. Development evolving: stylized facts

Although there were few outstanding success stories from the fourth quarter of the twentieth century such as those of the East Asian Tigers and a handful of European economies, belief in industrialization as the necessary pathway to development remained unshakeable until the Financial Crisis of 2008–2009 precipitated a Great Recession and a slowdown of global trade (Szirmai 2012).[5] Since then, five stylized facts compel a rethinking of growth drivers.

First, is the failure of most developing countries in Latin America,[6] SSA and some in South Asia to build a broad industrial base, which could anchor future prosperity—and diminish the reliance on resource-based products and exports (Figure 1). In fact, the share of manufacturing in GDP has either stagnated or declined in these regions since the 1990s.[7] The industrial backwardness of countries in SSA may be because of policy missteps, because of an unfavorable business environment, and because labor and capital costs in Africa for any level of GDP are higher than in Asian competitors (Gelb et al 2017; Figure 2). Moreover, early movers in East Asia, China, middle income economies in Southeast Asia, and a few South Asian countries have established a commanding lead in key export industries and their competitive advantage has slowed or prevented entry by latecomers (Yusuf 2023). Other challenges have also mounted (Szirmai et al eds. 2013). Whether the opportunities for latecomers will improve once the Southeast Asian economies (including China) transition away from light manufacturing remains to be seen.[8] Thus far, there is scant evidence that the so-called

5 Szirmai (2012) observes a correlation between industrialization and the level of economic development. This finding is reiterated by UNCTAD (2013). https://unctad.org/press-material/export-led-development-no-longer-viable-unctad-says-economies-will-perform-better; and Palley (2011).

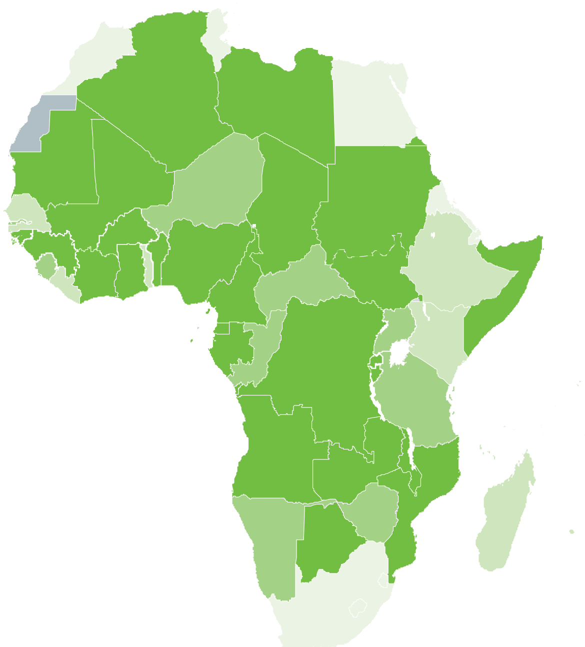
6 The trend in Mexico may be typical of developments in some other MICs. “A modern, fast-growing Mexico, with globally competitive multinationals and cutting-edge manufacturing plants, exists amid a far larger group of traditional Mexican enterprises that do not contribute to growth. These two Mexicos are moving in opposite directions. The largest companies are raising productivity by an impressive 5.8 percent a year, while the productivity of small, slow-growing enterprises is falling by 6.5 percent a year. And with employment growing faster in the traditional Mexico, more labor is shifting to low-productivity work.” Bolio et al (2014).

7 See WDI on the share of manufacturing in GDP for these regions. https://data.worldbank.org/indicator/NV.IND.MANF.ZS

8 Countries undergoing premature deindustrialization have lower overall levels of formal manufacturing activities; experience an early reversal of the industrializing trend; undergo both employment and output deindustrialization; and structural change frequently results in the growth of formal and informal services registering lower rates of productivity increase. UNIDO (2016); and Kirsch (2018).

"premature deindustrialization" afflicting developing economies can be reversed (Rodrik 2013; 2015; World Bank 2017).[9]

FIGURE 1. Commodity dependence of African countries



Source: UNCTAD (2022b). https://unctad.org/system/files/official-document/aldcafrica2022_en.pdf

FIGURE 2. Manufacturing input costs compared: Bangladesh vs. African countries

	Labour Cost Per Worker	Capital Cost Per Worker	GDP Per Capita	WEF Competitiveness Rankings
Bangladesh	$835.31	$1,069.84	$853.02	106
Kenya	$2,118.01	$9,775.45	$1,116.69	96
Tanzania	$1,776.65	$5,740.99	$1,094.95	116
Senegal	$1,561.64	$2,421.98	$775.45	112
Ethiopia	$909.28	$6,137.98	$471.19	109

Source: Gelb et al (2017).

9 Atolia et al (2018) trace the deindustrialization (more of labor than of output) to "intense competition among a number of countries for relatively stable global demand for manufacturing goods, deficiency in complementary public fundamentals needed to attract foreign capital, technology, and skills, and the leveraging effect of globalization, which magnifies initial differences in fundamentals of these countries." Kruse et al (2021) Find that the share of the workforce engaged in manufacturing in the 18 sub-Saharan economies included in their sample rose by 1.2 percentage points to 8.4 percent during 2010–2018. Small scale firms (many informal) producing low quality goods for the domestic market were responsible for most of this increase and hence manufacturing productivity has remained low.

Second, is the stability or decline in the share of capital formation in total spending. A few countries mostly in East and Southeast Asia, sourced growth in the earlier stages of development from high rates of domestic investment, but they were the exceptions. Over the past decade, gross capital formation has leveled out or fallen throughout the developing world including in Southeast Asia.[10] Capital remains the leading growth driver for countries in the low- and middle-income categories, but at current rates, it cannot alone push countries into high, single digit rates of growth (Figure 3). Moreover, capital has tended on balance to flow from developing to developed economies (Lucas Paradox)—i.e., to flow uphill.[11]

Hence the emerging prominence of the third stylized fact: most long-term growth will be a function of total factor productivity (TFP). It is factor productivity that explains much of the gap in incomes between African nations and high-income countries (Jones 2016 and 2022; Klenow and Rodriguez-Clare 1997; and Clark and Feenstra 2003). If TFP is indeed central to growth performance over the longer term, then the gap in productivity presents opportunities for catching up, a process that appears to have slowed. In 1990, the average TFP of other countries was 67 percent of the United States (Yusuf 2003). By 2014, it was 60 percent.[12] A few countries caught up with the United States because of improvements in TFP. The majority saw the gap widen because either TFP did not increase, or it grew more slowly than it did in the U.S. Countries in SSA such as South Africa and Nigeria saw their per capita GDP decline relative to the global average (Figure 4). "In all regions, the TFP gap explains 60–70 percent of the total gap in output per worker. From 2000 to 2010, the TFP gap increased its explanatory power of the GDP per worker gap" (De Gregorio 2018, p.8; Cusolito and Maloney 2018).[13] In particular, the TFP level of African firms engaged in manufacturing trails the level of comparable firms in other developing countries (Figure 5).[14]

10 WDI (2023). https://data.worldbank.org/indicator/NE.GDI.TOTL.ZS

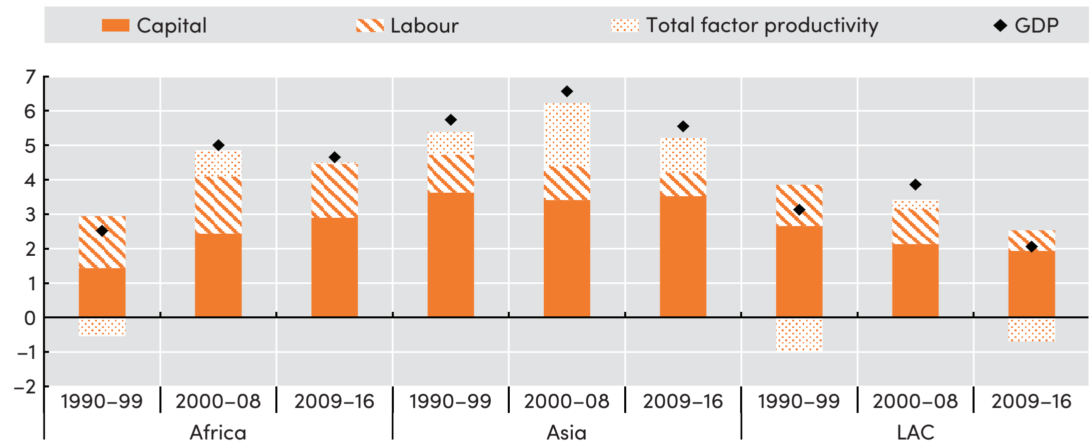
11 Several reasons have been put forward to explain this apparent paradox including institutional shortcomings (esp. governance), higher risk premia (which rose following the Covid pandemic), the lack of human capital, infrastructure gaps, and security issues. Gros (2013); Alfaro et al (2003); Cubeddu, Obstfeld and Boz. (2017). Lucas (1990); UN (2022). After falling sharply in 2020, FDI in developing countries rebounded in 2021 but with little of this going into greenfield investment. The Ukraine conflict and recessionary pressures that are likely to persist through 2023, will be a drag on FDI. UNCTAD (2022a).

12 Although African countries have been converging with respect to life expectancy and years of schooling, this has not matched by GDP per capita or technology adoption. Paprotny (2020); Johnson and Papageorgiou (2020).

13 A recent World Bank (2021) report on Cote d'Ivoire highlights the need to enhance productivity if the country is to double its GDP by 2030, the desired target; https://blogs.worldbank.org/africacan/higher-productivity-can-shape-future-cote-divoires-growth

14 SSA's agricultural output also falls well short of potential because the low productivity of smallholder farms. McKinsey (2019).

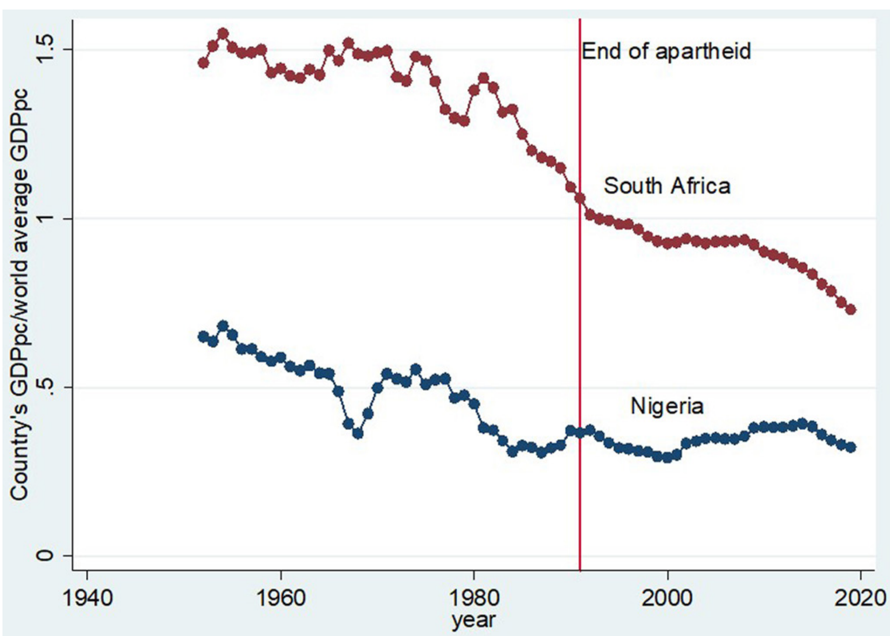
FIGURE 3. Sources of growth in developing countries



Note: TFP stands for total factor productivity, measured as the variation in GDP not explained by the contribution of labour and capital to GDP.

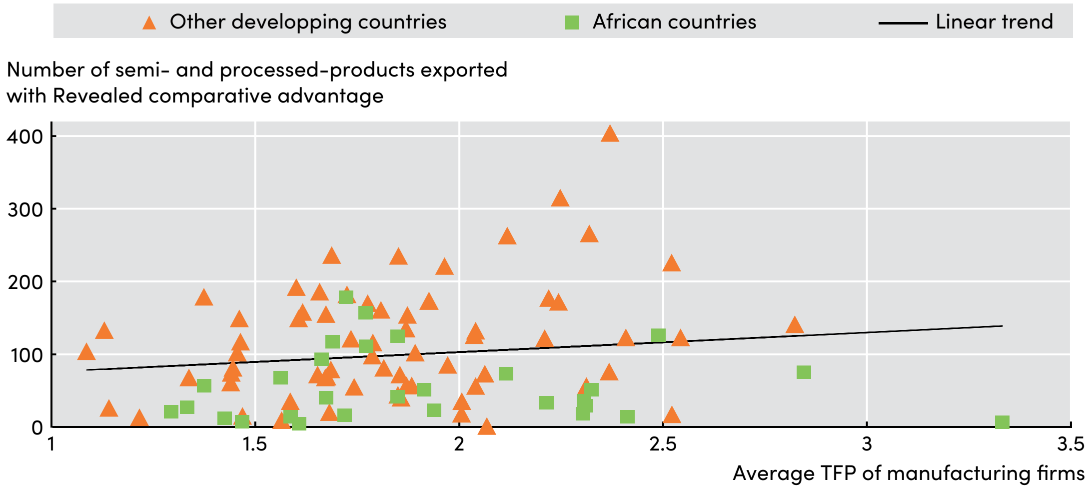
Source: https://www.oecd-ilibrary.org/docserver/9789264302501-en.pdf?expires=1553443820&id=id&accname=guest&checksum=AA19D4F1BB0F88B68BC13DAB7B68F159

FIGURE 4. GDP per capita compared to the rest of the world in South Africa and Nigeria, 1940–2020



Source: B. Milanovic based on PWT 9.0. 'In relation to the World average.' https://twitter.com/brankomilan/status/1361479731510730753

FIGURE 5. TFP of manufacturing in African and other developing countries

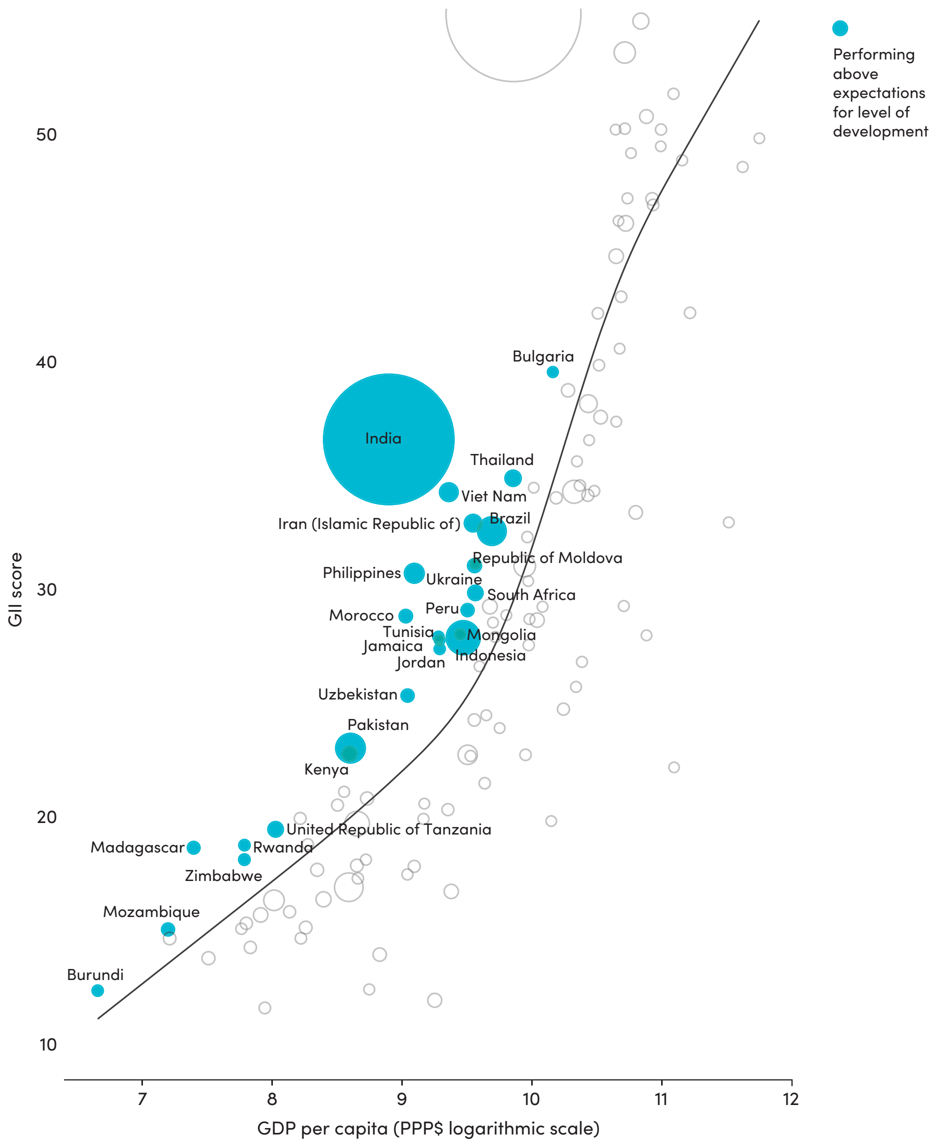


Source: https://www.oecd-ilibrary.org/docserver/9789264302501-en.pdf?expires=1553443820&id=id&accname=guest&checksum=AA19D4F1BB0F88B68BC13DAB7B68F159

Narrowing the productivity gap and in the process, accelerating growth depends largely on the fourth stylized fact. Developed and developing countries alike must now look to technology and innovation backed by a deepening of (skilled, technical) human capital[15] to steer their economies towards sustainable prosperity as can be seen in Figure 6.

15 Technological change is becoming more skill-biased and capital intensive and workers with both technical and soft skills will be the ones in greatest demand and command higher wages. The advances in AI and the increasing use of robot capital, which can substitute for unskilled workers, could widen the divergence between developed and developing economies, unless the latter step up their efforts to strengthen their base of skills and increase investment in technology. Alonso et al (2020); Acemoglu and Autor (2011); Behar (2013); Acemoglu and Restrepo (2020). conclude that automation of existing tasks is increasing the demand for skills and new tasks are also more skill intensive.

FIGURE 6. Per capita GDP and innovation capability



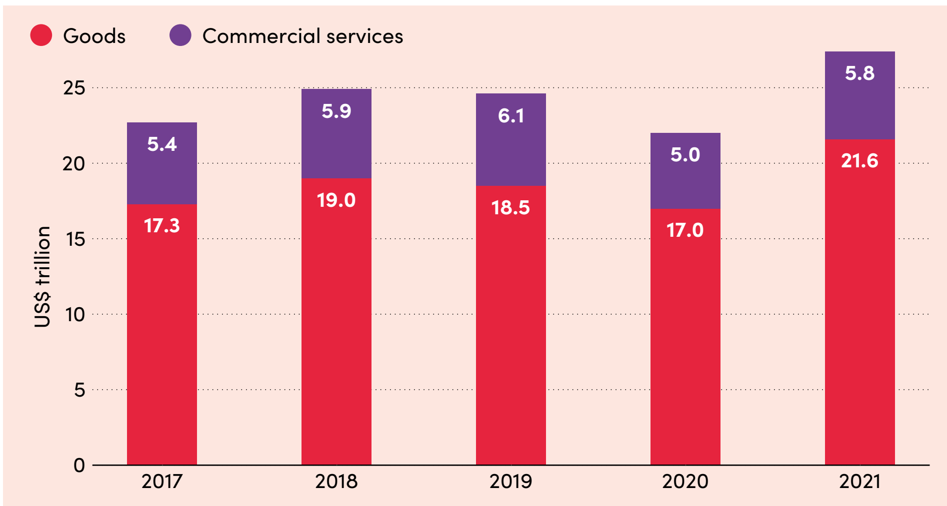
Note: Bubbles sized by population. The cubic spline trendline shows the expected levels of innovation performance at different levels of GDP per capita for all economies covered in the GII 2022.
Source: GII 2022. Figure 11. p.47. https://www.globalinnovationindex.org/userfiles/file/reportpdf/gii-full-report-2022.pdf

A fifth stylized fact related to technological change is the increasing share of services as a percent of GDP and of trade in services both direct and indirect. This will tilt structural change further in the direction of services,[16] including digitalized tradable services especially if trade reforms lower the

16 Hsieh and Rossi-Hansberg (2020) point to the technological advances that are responsible for the successful growth and concentration of non-tradable services in the United States. Firms supplying retail, wholesale, and other services "have adopted technologies that enable them to standardize and scale up the delivery of non-traded *services*. In this sense, what has happened in non-traded services is akin to the industrial revolution unleashed by Henry Ford more than a hundred years ago when Ford introduced mass production to a car industry dominated by independent artisans."

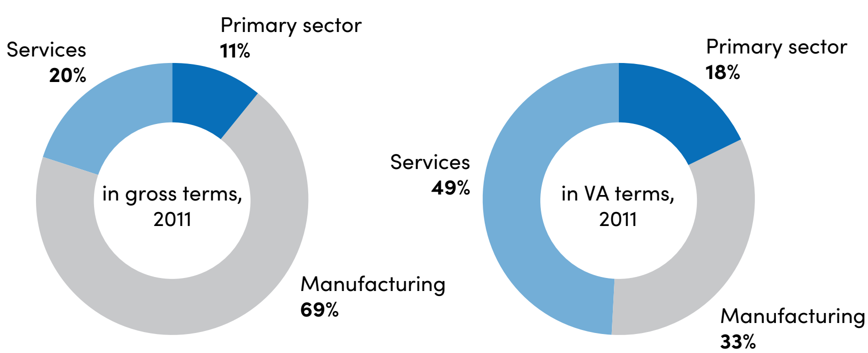
barriers to trade in services.[17] Although the value of direct services in global trade has changed little since 2017 (Figure 7), once trade is measured with reference to value added and all indirect services (for example, in servitized manufacturing) are included, 49 percent of world trade was comprised of services in 2011 and has probably risen since (Figure 8: WTO 2010).[18]

FIGURE 7. Trade in goods and services 2017–2021



Source: WTO (2022). https://www.wto.org/english/res_e/booksp_e/wtsr_2022_c2_e.pdf

FIGURE 8. Structure of world trade



Source: WTO (2017). https://www.wto.org/english/res_e/booksp_e/aid4trade17_chap4_e.pdf

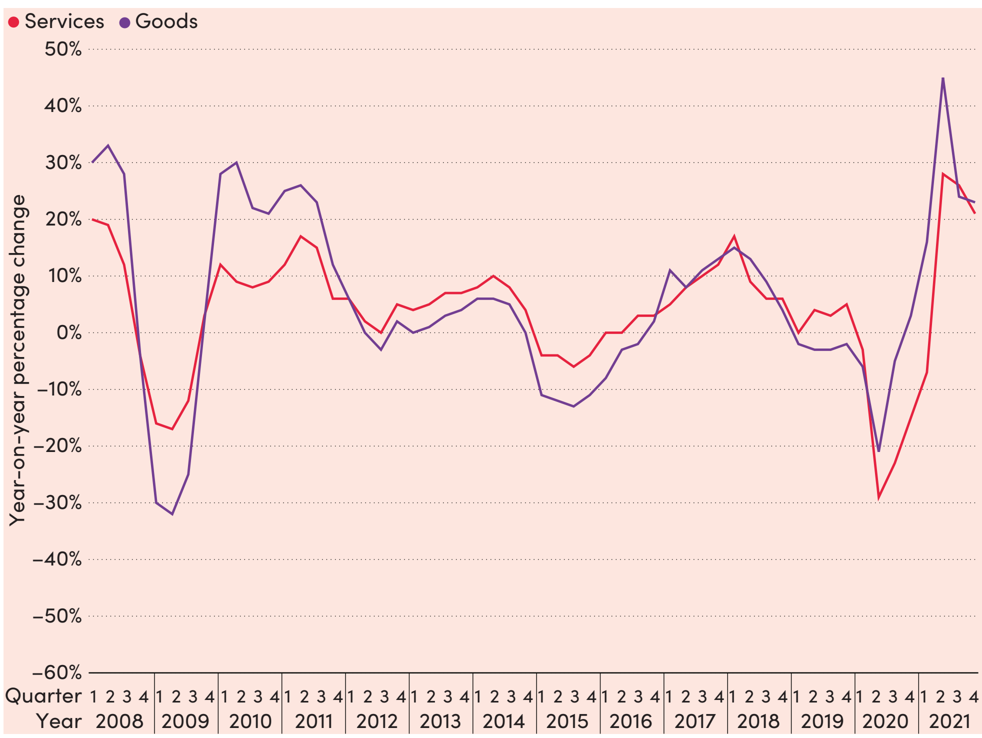
Growth of trade in services outpaced that of goods between 2005–2019. Global trade of both goods and services declined in 2020, with a steep recovery in 2021 (Figure 9). By 2022, services were rising faster than merchandize trade at an estimated 14.6 percent rate with growth of services exports from

17 Alessandria, Johnson, and Yi (2021) observe that the removal of trade restrictions and the participation in global value chains influence the allocation of resources and economic structure. "Lower barriers facilitate specialization through several forces, the most prominent of which are comparative advantage and economies of scale."

18 WTO (2010) https://www.wto.org/english/res_e/statis_e/services_training_module_e.pdf

developing economies exceeding those from developed countries (Figure 10).[19] Among the developing economies, China and India led the field, however, exports of some African countries rose at double digit rates in 2021 and amounted to $124 billion in 2019 (UNCTAD 2022b). Given that they are a small fraction of the total, there is abundant scope for expanding the share (Figure 11). However, African countries will have to diversify away from traditional tradable services such as travel and transport and harness digitization to gain the full benefits of innovation and services trade.[20] The UNCTAD (2022b) observes. "ICT directly affects the quality (complexity) of products and facilitates product differentiation and customization, with positive impacts on the variety of firms' outputs. [Furthermore] its embedded digital platforms and applications are increasingly having a positive impact on information asymmetries and greater market access for both large and small firms." Prior to the onset of the Covid pandemic, the WTO projected that the share of services in global trade could be 50 percent higher in 2040 and developing countries could add 15 percent to their share of the total.

FIGURE 9. World trade in goods and commercial services 2008–2021 (y-o-y % change)

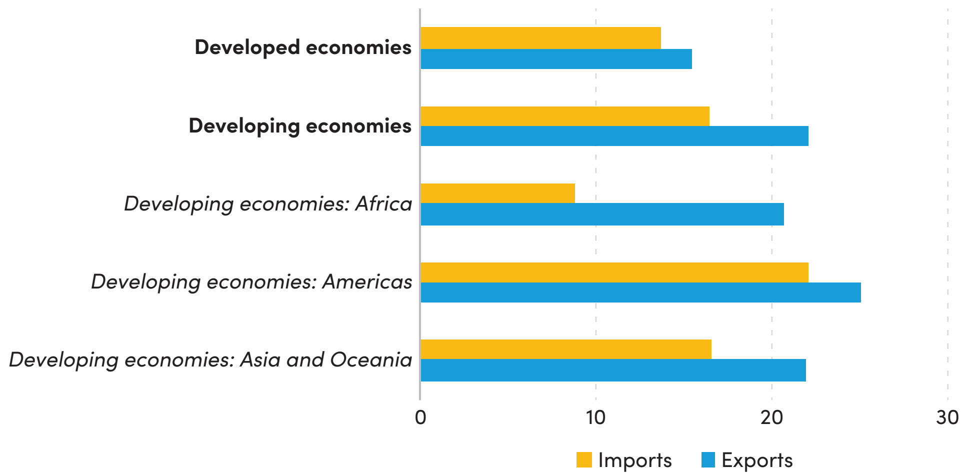


Source: WTO (2022). https://www.wto.org/english/res_e/booksp_e/wtsr_2022_c2_e.pdf

19 The Covid pandemic by depressing travel and tourism cut services trade by 18 percent in 2020 however, revival in 2021 and 2022 was led by travel, transport, computer, and insurance services. https://www.wto.org/english/res_e/statis_e/daily_update_e/serv_latest.pdf; https://www.wto.org/english/res_e/statis_e/daily_update_e/serv_latest.pdf

20 Exports of services from African countries amounted to 17 percent of total exports. UNCTAD (2022b). The desirability of services diversification and of taking advantage of digitalization is the message of a second report from UNCTAD (2022b). Rethinking the foundations of export diversification in Africa: The catalytic role of business and financial services. https://unctad.org/edar2022; According to Feenstra and Kee (2004) a 10 per cent increase in export variety leads on average, to a 1.3 per cent increase in productivity because resources are allocated and used more efficiently.

FIGURE 10. Growth rate of services trade in 2021



Source: UNCTAD (2022a). https://hbs.unctad.org/total-trade-in-services/

FIGURE 11. Exports of services from developing economies

Developing economies

Exporter (Ranked by Value)	Value (Billions of US$)	Share in World Total (Percentage)	Annual Growth Rate (Percentage)
China	(e) 392	(e) 6.5	(e) 39.8
India	241	4.0	18.5
Singapore	230	3.8	9.6
United Arab Emirates	102	1.7	30.4
China, Hong Kong SAR	77	1.3	14.7
Developing economies	**1,651**	**27.2**	**22.1**

Developing economies: Africa

Exporter (Ranked by Value)	Value (Billions of US$)	Share in World Total (Percentage)	Annual Growth Rate (Percentage)
Egypt	(e) 22	(e) 0.4	(e) 45.5
Morocco	15	0.3	11.5
Ghana	(e) 9	(e) 0.2	(e) 20.6
South Africa	9	0.1	5.2
Ethiopia	(e) 6	(e) 0.1	(e) 25.0
Developing Africa	**100**	**1.7**	**20.6**

Source: UNCTAD (2022a). https://hbs.unctad.org/total-trade-in-services/

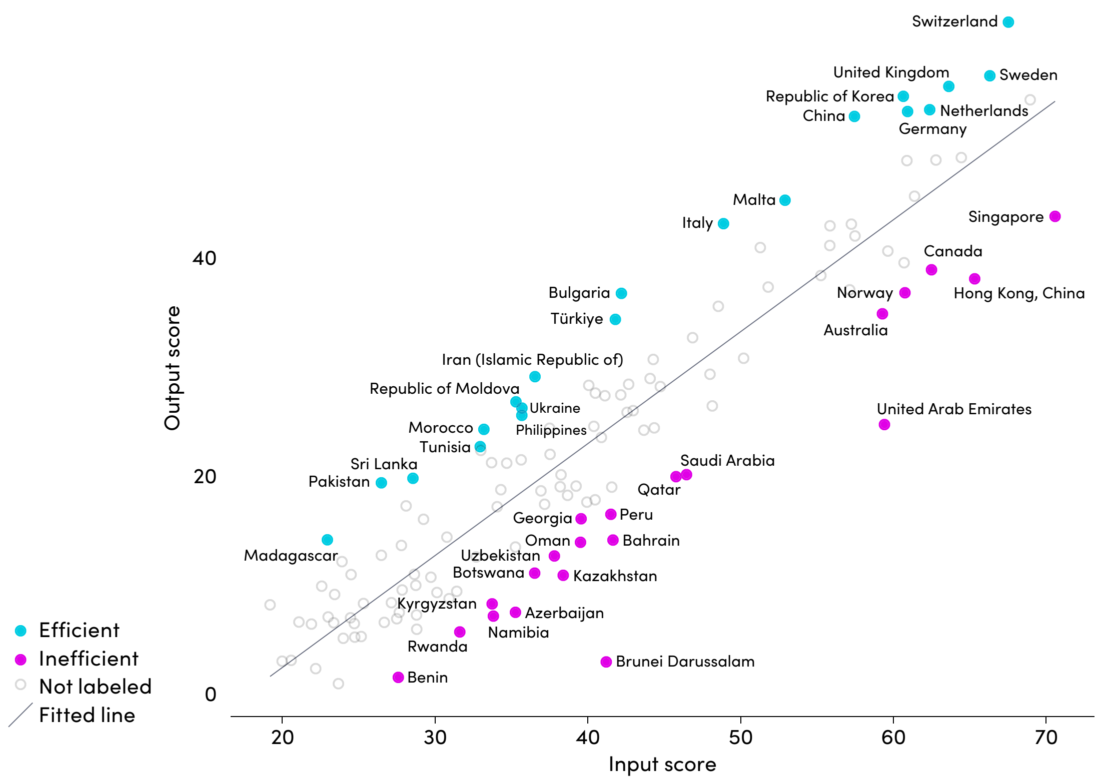
2. Technology and innovation in SSA: opportunities and gaps

This shift in the thinking on development strategy and the stylized facts underpinning it have major implications for African countries. The technology gap presents an opportunity to raise productivity and incomes with greater rapidity. As Alexander Gerschenkron (1962) observed, late starting countries were not necessarily disadvantaged. In fact, they could telescope the development process by harnessing proven technologies. It requires building market institutions, improving the business environment, adopting enabling trade and macroeconomic policies, and mobilizing resources, which have demonstrated their worth in other countries. Furthermore, latecomers can minimize false starts and avoid dead ends by learning from the experience of early movers and adapting technology policies to accommodate their own circumstances and global developments.

However, countries in SSA have a lot of ground to cover and they need to build the complementary factors that facilitate technology absorption (Cirera and Maloney 2017). The Global Innovation Index for 2022, includes only seven countries in SSA in the first 100 with twelve in the bottom 10 percent (out a total of 132 countries, GII 2022). The top performers were Mauritius (ranked 45), South Africa (61), Kenya (88), Botswana (86), Ghana (95), Namibia (96) and Senegal (99).[21] South Africa ranked 48 in 2018 has seen its ranking slip, and Botswana (from 74), while Mauritius improved its ranking (61 in 2018) as did Kenya (from 91).[22] In virtually all cases (Madagascar being the anomalous outlier), output performance scores fell short of the scores for inputs (Figure 12).[23] Moreover, productivity of countries in SSA trailed the rest as they had done in 1970 (Figure 13). And predictably, countries in SSA have been unable to nurture innovative industrial clusters although a few green shoots are emerging in Nairobi and Lagos (Figure 14; Lashitew 2022).[24]

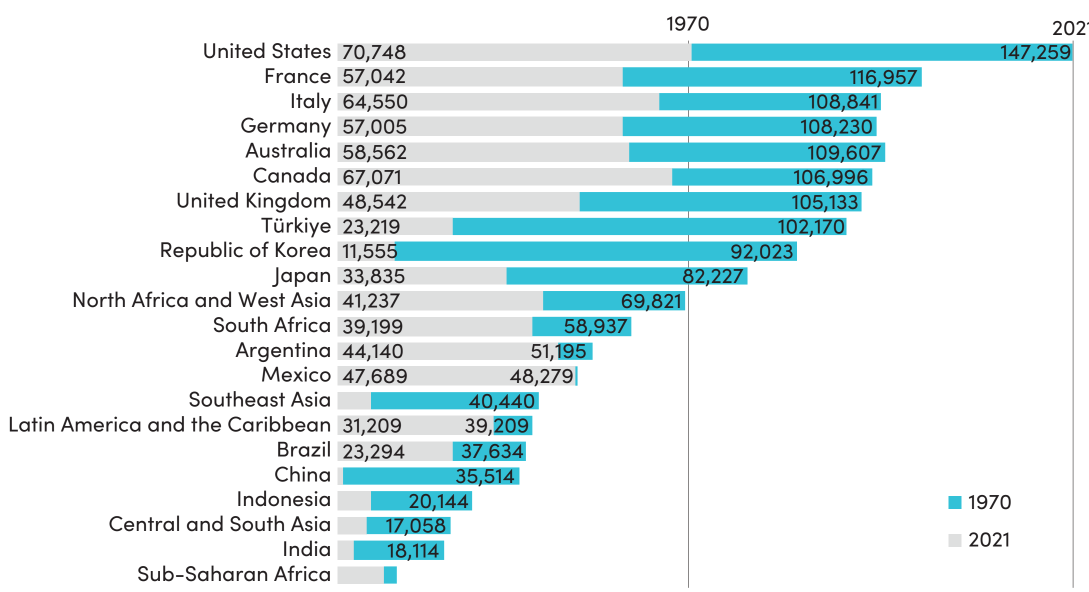
21 https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2020.pdf
22 https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2018-intro5.pdf
23 The calculation of the scores is spelled out in GII 2022 results chapter.
24 The Africa Leapfrog Index attempts to gauge the potential of leading candidate countries such as Kenya, Nigeria, South Africa, and Rwanda. https://sites.tufts.edu/digitalplanet/african-leapfrog-index/; Fintech start-ups are enjoying a boom but according to McKinsey (2022) they face four challenges. "Reaching scale and profitability, navigating an uncertain regulatory environment, managing scarcity, and building robust corporate governance foundations."

FIGURE 12. Innovation input to output performance 2022



Source: Global Innovation Index 2022 (Figure 12; p.53).

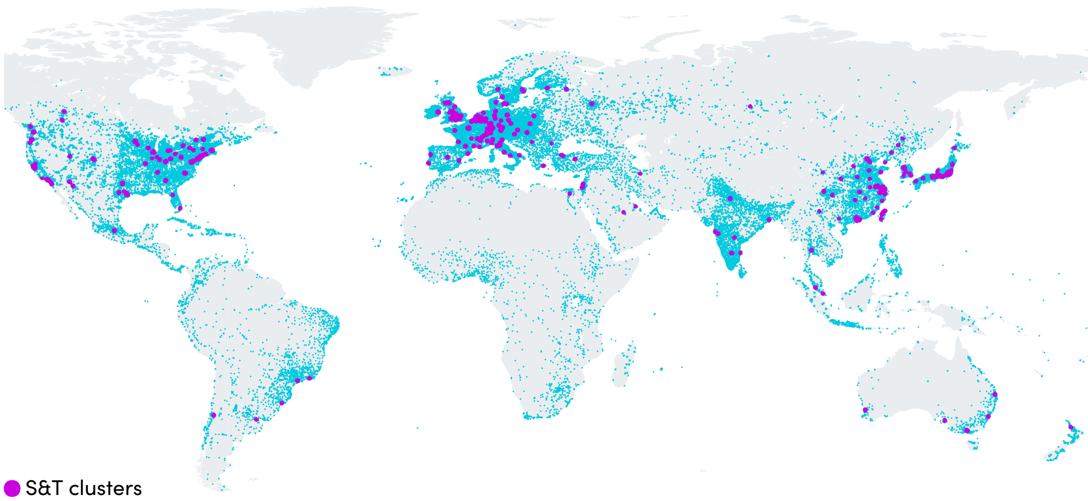
FIGURE 13. Productivity levels in selected economies and regions 1970–2021



Notes: Real GDP levels are expressed in 2021 international dollars, converted using purchasing power parity (PPP); productivity refers to GDP per worker.

Source: Global Innovation Index 2022 (Figure 22).

FIGURE 14. Location of top 100 global innovation clusters



Note: Noise refers to all inventor/author locations not classified in a cluster.
Source: Global Innovation Index 2022 (Map 1).

The perceived technological backwardness and productivity drought persuaded the African Union (AU) to adopt the Science Technology and Innovation Strategy for Africa 2024 (STISA-2024)[25] in 2014. It initiated a multi-pronged effort to tackle six priorities by promoting technological innovation in agriculture, energy, environment, health, infrastructure development, mining, security, and water (Figure 15).[26] In addition, the strategy included four mutually reinforcing pillars: (i) building and/or upgrading research infrastructures; (ii) enhancing professional and technical competencies; (iii) promoting entrepreneurship and innovation; and (iv) providing an enabling environment for STI development in SSA. STISA-24, which is an integral part of the AU's Agenda 2063, expects to "Accelerate Africa's transition to an innovation-led knowledge economy" by building technical and institutional capacities and fostering entrepreneurship which benefits innovation, raises productivity and helps African economies achieve rapid and inclusive growth (Asongu 2020). In pursuit of these objectives regional networks and implementation mechanisms have been mobilized in support of 'flagship programs 'in the areas of biosciences, biotechnology, biosafety, laser technology, water and energy and others that measure the support that ST&I can offer to evidence-based policymaking (STISA 2024). This is work in progress.

25 https://www.nepad.org/blog/towards-achieving-science-technology-and-innovation-strategy-africa-2024
26 https://au.int/sites/default/files/newsevents/workingdocuments/33178-wd-stisa-english_-_final.pdf

FIGURE 15. AU priorities for research

Priorities	Research and/or Innovation Areas
1. Eradicate Hunger and ensure Food and Nutrition Security	• Agriculture/Agronomy in terms of cultivation technique, seeds, soil, and climate • Industrial chain in terms of conservation and/or transformation and distribution infrastructure and techniques
2. Prevent and Control Diseases and ensure Well-being	• Better understanding of endemic diseases: HIV/AIDS, Malaria Hemoglobinopathie • Maternal and Child Health • Traditional Medicine
3. Communication (Physical and Intellectual Mobility)	• Physical communication in terms of land, air, river, and maritime routes equipment, infrastructure, and energy • Promoting local materials • Intellectual communications in terms of ICT
4. Protect our Space	• Environmental Protection including climate change studies • Biodiversity and Atmospheric Physics • Space technologies, maritime and sub-maritime exploration • Knowledge of the water cycle and and river systems as well as river basin management
5. Live Together—Build the Society	• Citizenship, History, and Shared values • Pan-Africanism and Regional integration • Governance and Democracy, City Management, Mobility • Urban Hydrology and Hydraulics • Urban Waste management
6. Create Wealth	• Education and Human Resource Development • Exploitation and management of mineral resources, forest, aquatics, marines, etc. • Management of water resources

Source: Juma and Serageldin (2014).

STISA-24 is both necessary and ambitious. For it to succeed, the state in African countries will need to substantially increase investment in R&D currently far below 1 percent of GDP with downstream developmental activities absorbing most of the resources. Over time, as per capita GDP rises and the capabilities of the business sector increase, it would need to play a larger role. The strategy must go hand in hand with reform measures pertaining to education and finance so that research and innovation is not starved of human capital and financing.

From Figure 16 it is apparent that the bulk of the resources currently ploughed into R&D either come from public sources or in some cases from IFIs or bilateral donors (Gross expenditures on R&D—GERD). Also, notable (from Figure 17) is that in several countries a fifth or more of the modest sums available are disbursed for 'basic research' when at the stage of development these countries are at, applied or experimental research and reverse engineering would yield higher returns. With so much proven technology to draw upon, assimilation of the available knowledge rather than innovation (that is ‘new to the world’) promises a larger payoff over the medium term (Asongu 2017). Akinwumi Adesina, president of the African Development Bank, observed that “technologies to achieve Africa’s green revolution exist. For the most part, they are all just sitting on the shelves.” “The deployment of these technologies poses a great entrepreneurial challenge.” (Watkins 2019).

Predictably, the stock of researchers is low and some of the best young scientists seek opportunities abroad. The number of full time equivalent (FTE) researchers per million people was 28 in Uganda, 91 in Ethiopia, and 19 in Tanzania. South Africa and Senegal were higher on the scale with 484 and 564 respectively. But African countries fall far short of the levels of middle-income countries such as Vietnam (757), Thailand (1,790) or Malaysia (2,185) or high-income countries such as the Netherlands (5,912) or Finland (7,527).[27]

FIGURE 16. GERD by sources of funding: 2014/2015

Country	Business (%)	Government (%)	Higher Education	Private Non-Profit (%)	Rest of the World (%)
Botswana	18.0	60.0	1.0	0.0	21
Eswatini	13.0	35.0	19.0	2.0	31
Ethiopia	1.0	97.0	0.0	0.0	2
Mozambique	0.5	43.5	13.3	0.0	42.7
Namibia	11.0	63.0	6.0	4.0	16
South Africa	41.0	43.0	1.0	2.0	13
Uganda	4.0	38.0	2.0	3.0	53

Source: African Innovation Outlook 2019.

FIGURE 17. GERD by type of R&D: 2014/2015

Countries	GERD	Basic Research	Applied Research	Experimental Development	Not Elsewhere Classified
Eswatini	100.0	20.4	66.1	13.5	–
Ethiopia	100.0	1.3	24.4	74.0	0.2
Mali	100.0	11.9	58.4	28.7	1.05
Mozambique	100.0	27.1	51.0	21.9	–
Namibia	100.0	17.1	44.8	30.4	7.8
South Africa	100.0	23.8	47.3	28.9	–
Uganda	100.0	29.2	47.1	23.6	–

Source: African Innovation Outlook 2019.

From the performance to date, it appears that the research and innovation capabilities of both government research institutes and of universities, are extremely limited. A few large firms conduct applied research much of it to customize products for African markets however, most technological advances are embodied in machinery and equipment purchased from abroad

27 Data from UNCTAD (2022a). https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6

(African Union 2020a). Even the leading firms have been slow to introduce organizational changes and accumulate intangible capital, which would facilitate innovation, or to take full advantage of digital technologies.[28] SSA's innovation deficit and productivity shortfall is exacerbated by the overall shortage of tertiary level skills, low rates of enrollment (3 percent of all student enrollments in the region) and the poor quality of higher education (Yusuf et al 2009; World Bank 2020).[29] Furthermore, brain drain, which depletes the ranks of the some of the most talented technical personnel (in particular health workers, Labonte et al 2006) reduces productivity growth with smaller states affected more severely and it is also partially responsible for the current account deficits in SSA countries (Schiff and Wang 2009).[30]

A turnaround in SSA's economic fortunes rests on a clear recognition by governments that growth must necessarily be hitched to advances in technological capabilities, investment in supporting ICT infrastructure so as to provide the majority of the working population with affordable access to broadband, and an increase in home grown innovation for example in agriculture all within a domestic and regional institutional context favoring innovation (Asongu 2017; OECD 2021). Governments will need to be far more proactive in nurturing basic skills, in financing and incentivizing the accumulation of research capital through their support for major research institutions[31] and stimulating large firms and fast maturing start-ups to deliver the innovation,

28 Broadband penetration and access to Internet services remains limited. The growth of firms is hampered not only by the business environment but also by the fragmentation of the continental market. SSA is fragmented geographically. The fragmentation extends to trade zones of which there are sixteen and also to logistical fragmentation caused by numerous transport bottlenecks and internal barriers to trade. BCG (2018) https://www.bcg.com/publications/2018/pioneering-one-africa-companies-blazing-trail-across-continent; UNCTAD (2020); Ambitious plans are spelled out in the African Union (2020b)

29 The UNCTAD (2020) report on Uganda observes deficiencies in the education system that are prevalent in other African countries as well. "The education sector in Uganda is … constrained by many challenges, among which, a lack of qualified education professionals, and curricula that do not match the needs of students, nor of sectors and industries, are critical. Ideally, university and tertiary education would develop closer coordination with sectors and industries to produce adequate numbers of science, technology, engineering, and mathematics (STEM) graduates with innovation mindsets, as well as the competency and confidence to step easily into professional life upon graduation."

30 https://www.universityworldnews.com/post.php?story=20180209080048133; https://en.unesco.org/courier/january-march-2018/african-brain-drain-there-alternative; Coulibaly (2020); An overseas diaspora does have some advantages. It is a source of network externalities, of entrepreneurship and of remittances. For a discussion of the pros and cons, see Docquier and Rapoport (2011).

31 C. Juma (2016) makes the case for innovation universities, "that combine research, teaching, community service and commercialization in their missions and operations. They would depart from the common practice where teaching is carried out in universities that do little research, and where research is done in national research institutes that do not undertake teaching. Under this model, there is little connection with productive sectors. The idea therefore is not just to create linkages between those activities but to pursue them in a coordinated way under the same university structure… The ministries or agencies responsible for higher education will need to be creative and flexible enough to foster the creation of such universities while granting the autonomy necessary for them to advance their specialized innovation objectives… Creating innovation universities will require high-level coordination because of the increase in number of governmental and nongovernmental actors. High-level coordination of these activities must be strengthened within the offices of presidents and prime ministers."; See also Biasi et al (2021).

the productivity gains and much of the growth impetus.[32] Governments and large businesses will need to work together and to date, governments are not focused on the new growth strategy and too few firms grow and acquire the innovation capabilities to move the productivity needle (Figure 18).[33] The ethnic segmentation of the private sector and ownership of many businesses in several African countries might affect government policy, the business environment, firm growth and competitiveness (Ramachandran et al 2009; Gelb et al 2014). The legacy of colonialism may also have retarded the pace of development (Nunn 2005; Nunn 2020; Dell 2010). It is critical that the Covid pandemic not dilute the attention given to technology policy and that countries use the crisis to "build back better and more knowledge intensive economies". In attempting this transition to an ST&I led growth strategy, countries in SSA can learn from some countries in East Asia such as the Republic of Korea (ROK) that exploited technological opportunities in the past and are adapting their current strategies to take account of a changing landscape of technology.[34] The experience of East European economies such as Poland and the Baltic States, is also of relevance.[35] In fact, some innovation is ongoing, but it remains "under the radar: and does not receive the support, financing and the organizational backing of large firms that would permit a scaling up. If the Covid pandemic accelerates the democratization of innovation, the crisis will not have been wasted" (EIU 2014).[36]

32 A comment by an observer of the Nigerian elections in early 2023 had this to say. "There is a worrying absence of conversation around science in the current election campaigns. Two of the three front-runners for the presidency mention science and technology in their manifestos but have no specific plans for boosting scientific research and innovation, either in the manifestos or on the campaign trail. This seems to be a mere box-ticking exercise. Politicians are not afraid to make big-ticket promises because the electorate rarely demands accountability, so the near-total silence on science, technology and innovation is a worrying harbinger of future neglect." El-Imam (2023).

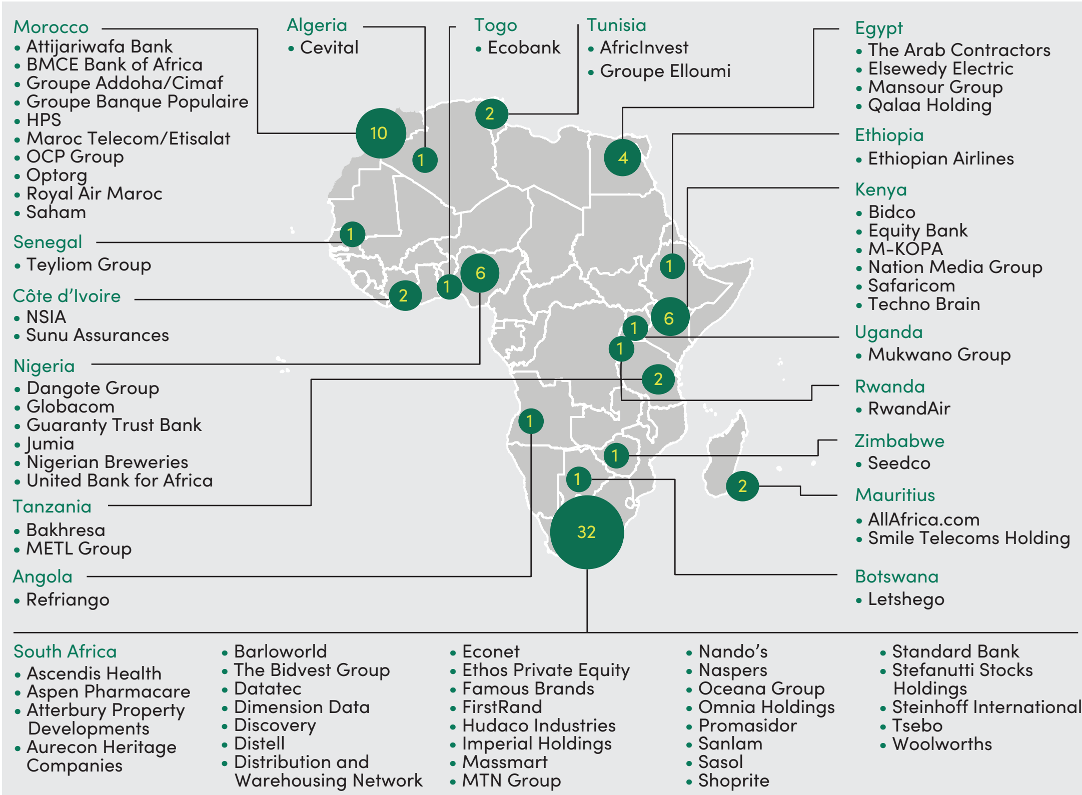
33 Research conducted by John Sutton for the IGC sponsored Enterprise Map Project found that the fewness of large firms—especially in the manufacturing sector—was one important hurdle for African economies. https://www.lse.ac.uk/Research/research-impact-case-studies/managing-sustaining-growth-african-economies; https://www.theigc.org/project/the-enterprise-map-series/; The space may have begun to fill according to consulting firms such as PwC, McKinsey, and BCG. "The continent has 400 companies with revenue of more than $1 billion per year, and these companies are growing faster, and are more profitable in general than their global peers. Yet Africa has only 60 percent of the number of large firms one would expect if it were on a par with peer regions—and their average revenue, at $2 billion a year, is half that of large firms in Brazil, India, Mexico, and Russia, for instance." But not all are in SSA. Many of the larger firms are from South Africa and Nigeria and most are in finance, telecommunications, transport, construction materials, and food processing. https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Middle%20East%20and%20Africa/Realizing%20the%20potential%20of%20Africas%20economies/MGI-Lions-on-the-Move-2-Executive-summary-September-2016v2.pdf; https://www.bcg.com/publications/2015/globalization-growth-dueling-with-lions-playing-new-game-business-success-africa; https://www.bcg.com/publications/2010/african-challengers; https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Middle%20East%20and%20Africa/Lions%20on%20the%20move/MGI_Lions_on_the_move_african_economies_Exec_Summary.pdf; https://www.pwc.com/ng/en/assets/pdf/lesg-companies-to-inspire-africa-2019.pdf

34 The efforts underway in Asia to digitize and stimulate ST&I are examined by Dabla-Norris et al (2023).

35 Discussion of how East European countries have absorbed technology and promoted digitalization can be found in Landesmann and I.P. Szekely eds. (2021); and Piatkowski (2019).

36 The EIU (2014) underscores the importance of frugal innovation for developing countries. "This is the area with the highest potential and is, currently, the most underserved. At one end of the frugal innovation scale is *jugaad*—often considered to be India's great contribution to global innovation. *Jugaad* refers to quick-fix solutions, usually developed by individuals to address the practical problems of daily life within severe resource constraints. At the other end is what I call *jhakaas* (Hindi slang for "wow!"): sophisticated but frugal thinking that could well trigger new technological trajectories that could disrupt even Western markets."; This theme is elaborated by Xiaolan Fu and others in Fu (2020).

FIGURE 18. Leading African companies



Source: BCG (2018). https://www.bcg.com/publications/2018/pioneering-one-africa-companies-blazing-trail-across-continent

The attention given to digital technologies (e.g., machine learning) and the belief that this is a general-purpose technology (GPT) with potential equivalent to electricity and the internal combustion engine has tightened the consensus regarding the future role of ST&I. It has also resulted in a search for new success stories linked to technological innovation and a reexamination of earlier stories in order to highlight the contribution of ST&I. One success story of long standing is that of Korea, a charter member of the Four East Asian Tiger economies and a model for all late starters. Viewed through the prism of technology, it is apparent that the sustained focus on industrialization and exports was only a part of the reason why the tempo of Korea's growth lasted as long as it did. The speed with which Korea (and more recently, China) assimilated technology, built up research capacity and has become an innovative economy, was of equal importance. This aspect of Korea's development has enhanced the relevance of the Korean model for developing countries now that the emphasis is on technology (rather than capital) as offering a surer path to growth when allied with factor inputs.

A steady accumulation of technological capabilities enabled Korea's rapid industrialization. The process of diversification and upgrading started with labor intensive light manufactures and extended into complex, technologically advanced, transport equipment, petrochemicals, consumer electronics, and semiconductors, and more recently, e-commerce and multimedia services. Together, these enabled Korea to sustain export-led growth over close to five decades. Although, countries in SSA such as Kenya, Rwanda, Nigeria, Mozambique, and Cote d'Ivoire, will not trace the exact path that Korea followed from the 1960s onwards, there are lessons of continuing relevance from Korea on how technology could accelerate the development of late starting economies and inform industrialization strategies, which remain the objectives of at least 26 African countries (OECD 2017a; Bhorat et al 2017).

Undoubtedly, both the industrial and the technological landscape has changed. African countries are likely to derive a smaller share of their growth from the production and export of manufactures but a few of the larger ones could achieve moderate levels of industrialization. Agriculture and services will play a larger role and the performance of these activities will depend on the effectively adopting and adapting ICT, other digital technologies, biotechnology, and technologies that tackle challenges posed by climate change and disease. How Africa could make progress in these areas is examined by the OECD (2021). Korean experience can inform the building of STI capabilities in SSA in each of these areas.

3. The Korean growth miracle from a technology perspective

Korea's swift ascent up the income ladder has at least three (overlapping) explanations.[37] The unwavering commitment of the political leadership and the business elite, starting with President Park Chung Hee in the mid 1960s and sustained by his successors, to a relatively inclusive, export-led industrial strategy entailing systematic diversification into more complex manufactures, is arguably the most frequently retailed.[38] The strategy itself was choreographed and implemented by Korea's economic bureaucracy headed by the Economic Planning Board (EPB) in consultation with the leading business groups.[39] The Five-Year Economic Development and Science and Technology Comprehensive Plans spelled out the government's vision and objectives. Presidential focus on industrial and export outcomes with reference to assigned targets and the attention given to cross sectoral coordination by the EPB mandarins, minimized failures that can short circuit linkage effects and stymie industrial change (Rodrik 1996).

The more 'neoclassical explanation for why Korea pulled ahead of comparators in Asia and Africa sidesteps industrial policy and instead emphasizes the crafting of an enabling environment

37 The distribution of land formerly owned by the Japanese to Korean farmers in 1949 may have contributed to the egalitarian distribution of income and political stability that buttressed Korea's later development. This redistribution was undertaken by the US. Military Government (USAMGIK). Kim (2016); Mitchell (1949).

38 Korea's geopolitical circumstances throughout this period motivated rapid industrialization: in particular, the threat from its northern neighbor and the possibility of diminished US support following President Nixon's speech in 1969 calling upon East Asian allies to shoulder more of their defense responsibilities.

39 Deliberation councils were among the vehicles used to conduct a continuing dialogue with the private sector.

incentivizing and steering private investment into promising industries.[40] This was complemented by public investment in energy and transport infrastructure and measures that deepened the skills of the workforce. This line of reasoning privileges market forces with the state playing an important supporting role, gives due attention to the initiative of private business conglomerates (chaebol) that spared no effort in penetrating foreign markets, and to (East Asian) neighborhood effects[41] that conferred reputational advantages and attracted the attention of foreign buyers and investors (Antras and De Gortari 2017; Easterly and Levine 1995; Vilarrubia 2006).

However, neither industrial policy nor market forces would have delivered the results Korea did achieve absent the great strides Korea made in absorbing and mastering technology from abroad and mustering home grown ST&I capabilities. This third explanation intersects with and underpins the other reasons put forward. Unlike many other developing nations, Korea perceived and grasped technological opportunities and put them to good use. The state took the lead in creating the foundations of what was to become Korea's innovation system.

The need to diversify Korea's industry and export more complex products motivated both industrial and technology policies from the mid 1960s. Technology was seen as essential to the success of industrialization and export competitiveness. MOST (Ministry of Science and Technology) and KIST (Korea Institute of Science and Technology) were established in order to promote technology transfer and absorption by Korea's nascent manufacturing sector. Incremental institutional additions continued through the 1970s and the 1980s with the creation of the Korea Advanced Institute of Science (now KAIST, the leading S&T university[42]), as well as a flock of specialized government research institutes (GRIs), many located in the Daedeok Science Town, which later morphed into the Daedeok Science Valley, housing public and private research entities employing thousands of highly trained professionals.

The state was equally active in expanding the schooling system and promoting tertiary education as well as vocational training. The efforts of the government were supported by strong popular demand for education (Lee 1997). The expansion of both public and private institutions gained momentum from the 1970s with Korean universities partnering[43] with leading western schools and largely displacing a system borrowed from Japan and Germany with the American model

40 The state created a controlled environment in which competition among Korean producers was encouraged but the market was protected by tariff barriers, and by restrictions on the entry and exit of firms. Moreover, Korean exporters were assisted by export subsidies, tax benefits and subsidized financing. Wade (2003).

41 One should not overlook, the threat South Korea faced from its neighbor to the North, a threat that drove the government to accelerate industrialization. Industrial diversification and deepening enabled Korea to meet more of its defense requirements and neutralize the pressure from its hostile neighbor.

42 *Nature* (2020) KAIST. https://www.nature.com/articles/d42473-020-00132-w

43 https://doa.korea.edu/archi_en/international/Partner_Universities.do

(Kim 2000).[44] Education especially in STEM disciplines and the development of industrial skills was also a priority from the very outset. Thousands of Korean students went abroad to study and links with foreign universities also facilitated a sharing of information on curricula and teaching modalities.[45] Industrial diversification could not have succeeded had the supply of human capital and workforce skills fallen short (Jung and Mah 2014).

Government institutions conveyed the state's vision to private entities and guided corporate policies and the allocation of their resources. By the 1980s, the chaebol were capitalizing on these initiatives and building their own research centers to harness the technologies they needed to compete in the global marketplace. From the very outset, Korea's ST&I was keyed to the advancement of tradable manufacturing activities and how Korea proceeded while instructive, might not necessarily be the path developing African nations will tread.

Industry building and technology assimilation

Korea's manufacturing in the 1960s revolved around light, labor intensive activities such as garments, footwear, toys, food products, and light consumer electricals. The kind that were the norm in other low income economies. But starting in the early 1970s, Korea initiated a structural break and launched its heavy and chemical industry promotion plan (HCIPP) so as to diversify into more complex and technology intensive products. It constructed a state-owned iron and steel complex at Pohang financed in part by Japanese grants, a machinery production complex at Changwon, a petrochemical complex at Wulsan,[46] an electronics complex at Kumi, and a major shipbuilding yard at Ulsan.[47]

The HCIPP was an ambitious and risky technological leap, one which several other countries also attempted, but only two East Asian economies took advantage of a window of opportunity for a latecomer[48] and landed squarely on their feet after some early wobbles.[49] The integrated steel mill

44 "Korean households simultaneously devoted much of their resources to education, thereby fueling a drastic expansion in education participation. Between the early 1980s and the mid-2000s, the country's tertiary gross enrollment ratio increased fivefold, while the number of students in higher education jumped from 539,000 in 1980 to 3.3 million in 2015… Korea is one of the top sending countries of international students worldwide after China, India and Germany. The number of Koreans enrolled in degree programs abroad peaked at 128,994 in 2011, after doubling from 64,943 in 1997." https://wenr.wes.org/2018/10/education-in-south-korea; Lee (1989); Shin (2012); Park (2015).

45 For example, the Minnesota Project (1955–61) sponsored by the International Cooperation Administration under the US State Department provided Seoul Nation University (SNU) with assistance (experts, equipment) enabling it to upgrade its engineering, medical, agriculture and public administration departments. Kim and Hwang (2000).

46 As private firms were reluctant to undertake risky, large-scale investments, the government constructed chemical plants of the requisite scale and subsequently transferred them to private ownership.

47 Later in the 1970s, other yards were constructed or expanded in Ok'po and Geoje. The development of Korea's shipbuilding industry is examined by Bruno and Tenold (2010).

48 Lee and Ki (2017) maintain that windows of opportunity are created by a new technology, by the weakening of incumbent producers (as in the US during the 1970s) and by industrial policy that allows new producers to enter and grow. At least two were available to Korean industry and POSCO was also able to buy the most advanced production equipment and thereby pull ahead of firms in the US.

49 The limited steel production capacity created by the Japanese, was destroyed during the Korean War. Korea was starting from a clean slate. Taiwan (China) also established an iron and steel industry, starting in 1974. Tien (2004).

at Pohang spearheaded the HCIPP and secured the supply chain for some downstream industries. Lacking domestic technical expertise and the tacit knowledge needed to attain the desired level of productivity and quality, Korea depended upon foreign capital, equipment and technical skills. Much of the capital and technology came from Japan, some was obtained from Austria and Germany. From the Japanese, Korea acquired oxygen enriched blast furnaces and continuous casting equipment. Koreans worked alongside their Japanese counterparts during the construction phase of the project and benefitted from knowledge transfer. Other workers were sent to Japan and Europe to receive hands on training at steel production facilities. Once the plant was commissioned in 1973, Japanese technicians continued to assist Koreans for a number of years familiarizing them with the working of the equipment and instilling the uncodified knowledge that allowed Pohang Iron and Steel Company (later POSCO) to reach peak efficiency levels. From the 1980s, onwards, POSCO was adopting and improving frontier technologies, investing in R&D and sourcing productivity gains from home grown innovations (Won and Choi 2003).[50] By the 1990s, POSCO now among the leading producers of steel in the world, was an innovator in its own right introducing Internet based control systems and factory automation that incrementally improved productivity (Enos and Park 1988).

The shipbuilding industry followed the template tested by iron and steel. (Bruno and Tenold 2010).[51] A domestic source of high-quality steel incentivized the production of ships while the exodus of many European shipyards[52] during the 1970s created space for new entrants (including Brazil) that could meet technical specifications and compete on the basis of price because Korean labor costs were lower, and firms were prepared to shave profit margins in order to gain entry.[53] That the Korean shipbuilders managed to elbow their way to the forefront of the shipping industry (helped by low interest loans from public institutions and the government's procurement policies) under demanding market circumstances caused by an oversupply of ships, testifies to their ability to become the technological equal of their rivals within a decade and compete in the market for container vessels, roll on-roll off ships, bulk and LNG carriers, and tankers.

Achieving technological parity with the established producers in Japan and Europe posed a considerable challenge because of the need to internalize intangible knowledge. Unlike the steel industry less of the shipbuilding technology is embodied in machinery. The quality of labor and technical skills is a more critical determinant of productivity. In order to truncate the process of learning, leading shipyards such as Hyundai Heavy Industries sought foreign assistance on such areas as ship designs, operating instructions, the design of dockyards, and production processes. They hired European engineers and technicians to assist with the running of the shipyard and training of the workforce and adopted quality control measures modeled on the best practices

50 https://ac.els-cdn.com/S147466701737595X/1-s2.0-S147466701737595X-main.pdf?_tid=5ded6951-7e87-49a1-acc5-b95bbd1e5543&acdnat=1545423530_c6c379e9f69afd341e27a06d38e2b5b9

51 http://www.ebha.org/ebha2010/code/media_168359_en.pdf

52 Worldwide overcapacity was the main cause.

53 In fact, shipbuilding did not turn in a profit for many years and in the early stages, it was sustained by subsidized financing from public institutions and the procurement of vessels by Korean shipping lines.

of leading competitors. This plus the recruitment of newly minted engineers from Korean universities—with some having received advanced training overseas—aided in the rapid upgrading of the workforce and allowed the shipyards to largely dispense with foreign assistance by the late 1980s. A more capable, tech savvy workforce plus learning by doing delivered substantial gains in productivity as well as in quality (Kim and Seo 2009).[54] These have continued into the present day with Korean firms among the frontrunners in the production of smartphones, autos, consumer durables, and engineering equipment.

Design capabilities took longer to acquire—close to fifteen years.[55] For some years ship designs were acquired from overseas and technology licensed to build new types of higher value ships such as LNG carriers. This dependence gradually tapered once in-house research and testing facilities had matured. During the latter half of the 1980s, Korean shipbuilders were responsible for advances in protective coatings, welding techniques and in core technologies related to ship propulsion, engine performance, and hull design to minimize pressure and friction drag.

Korea's world class auto industry has its roots in the Auto Industry Promotion Policy introduced in 1962 to create a new, protected infant industry. Korean firms entered into joint ventures with the likes of Mazda, Nissan and Ford to assemble cars using imported inputs (CKD kits). In order to build indigenous capability, only joint ventures were permitted by the government. Over the course of the next decade, intensive R&D efforts in particular by Hyundai (which had partnered with Ford), led to the introduction of the first Korean made car, the Pony. In producing the Pony, Hyundai leveraged technologies from a number of foreign suppliers in Japan, the UK and Italy. Technology transferred by Ford, which had partnered with Hyundai for over ten years, enabled the company to build and operate a dedicated assembly line for the new vehicle.

By the early 1980s, Hyundai penetrated the Canadian market with the "new Pony" (Excel) and in 1986, it began selling the Excel in the United States. By then, Hyundai had managed to source virtually all parts of the vehicle domestically thanks to the strong public backing for the auto parts industry and Hyundai's own intensive R&D. The creation of a vertically integrated ecosystem of suppliers was advantageous for the auto, shipbuilding, and other industries. Rapid technology acquisition was the key to success with the auto parts manufacturers closely collaboration with Hyundai and the other assemblers. While reverse engineering and research contributed to domestication, parts manufacturers relied on joint ventures and in-house R&D to access the more complex technologies.

54 This technology transfer paved the way to in-house R&D in shipping and in other industries. Chung and Lee (2015).

55 "At HHI (Hyundai Heavy Industry), production know-how improved relatively fast, while design technology, the ability to design ships, took longer to master. HHI was dependent on foreign ship designs for most of the 1970s even though the company started to acquire basic design abilities from as early as 1974. Gradually, HHI started to experiment with shipping designs and in 1978 a Basic Design Department was set up within the company. HHI's first self-designed ship was a 25,000-dwt bulk carrier ordered by Hyundai Merchant Marine in 1979. In the period 1978 to 1983, Hyundai was actively purchasing ship designs from other companies to increase their design technology. Other South Korean shipbuilders e.g., Samsung, also choose to use licenses as a mean for acquiring technology. In all 159 licenses were purchased by South Korean shipbuilders in the period from 1962 to 1987, paying a total of 117 million USD." Bruno and Tenold (2010).

Just ten years after the launch of the Pony, the Hyundai Excel was selling strongly in the North American market and gradually increased its share as Hyundai built up a reputation for quality and service.

The experience with the shipbuilding and auto industries was replicated by the electronics subsector. American companies such as Fairchild, Signetics, and Motorola had begun assembling transistors and semiconductors in Korea starting in the mid 1960s and by the end of the decade a little under 6 percent of Korea's exports consisted of these items. In 1975, MTI put forward a 6-year plan to promote wafer fabrication and the production of key electronic components using licensed technology to support Korea's entry into the production of consumer electronics such as TV sets and to lessen dependence on imports from Japan. The development of the domestic semiconductor industry was then integrated into the Fourth FYP (1977–1981). A public research institute—KIET (Korea Institute of Electronics Technology)—built Korea's first wafer fabrication facility to produce 16K DRAMs. Later in the decade of the 1970s, Samsung took over the joint venture Korea Semiconductor Inc and created Samsung Semiconductor Inc. in 1978. With the backing of EIAK (Electronics Industry Association of Korea) and KIET, other companies such as Goldstar, Daewoo and Taihan also perceived the opportunities in the electronics sector (computerization was gathering momentum as was the telecommunications sector) and the industry began attracting greater attention from officialdom (Kim 1996).

The Long-Term Plan for the Promotion of the Semiconductor Industry introduced in 1981 together with the investment of $400 million by the state, energized the private sector, which then took the lead (Kim and Kim 2006). Korean firms began actively seeking the technology that would close the gap with Japanese and American producers. Foreign firms such as AT&T and Nortel were persuaded to share technology in order to gain entry into Korea's telecom market. The chaebol also acquired technology through licensing and by financing smaller firms in Silicon Valley that needed to raise cash and were willing to share their product and process technology. In addition, Korean sentinel research centers in electronic industry hotspots gathered industrial intelligence. A strategy effectively used by Chinese and US firms as well in order to learn from competitors and also to tap into the markets for specialized expertise. These activities were complemented by an intensification of domestic research that accelerated technology assimilation. Korean manufacturers consolidated their position first in the back end of the industry in chip assembly, packaging and testing in the mid 1970s.[56] By the mid 1980s, the chaebol were manufacturing and exporting very large scale integrated (VLSI) circuits having accumulated expertise in the assembly and fabrication processes by importing foreign technology, trained a corps of engineers, invested massively in production facilities,[57] and created both public and private research facilities that were equipped to track, absorb, refine and extend the latest technologies. By the latter half of the 1980s, the leading chaebol had pulled abreast of their foreign competitors in the memory chip (DRAM) business and were pushing the technology frontier (Mathews and Cho 2000; Lee, J, W., 2013).

ST&I strategy 1970–1997

There is a pattern to Korea's technological development. In the earlier stages of industrialization when it was modernizing its light industries, Korea obtained technology through FDI and joint ventures. But this was done sparingly with the government emphasizing domestic technology capacity building over continuing dependence on foreign sources. A top-down effort aimed at attaining domestic technological autonomy was prioritized even more once Korea began diversifying into the manufacture of steel, chemicals, transport equipment, machinery, and electronics. The government supported industrial deepening by creating specialized research institutes and increasing its spending on R&D. The chaebol were incentivized by fiscal measures, subsidized financing,[58] government contracts, tariff free import of capital equipment embodying new technologies, exhortation, and veiled threats[59] so as to accelerate the process of borrowing and reverse engineering of products for which global demand was growing. The competition they encountered in global markets reinforced the pressure from the government.

Technology policy from the 1970s through the early 1990s was based on four pillars (shown in Figure 19; Kim 1997): (i) training of engineers and scientists by expanding STEM programs in Korean universities, sending students abroad to acquire advanced skills, and recruiting Korean scientists residing aboard mainly in the US. This was paralleled with the training of line workers in vocational institutions and with the help of foreign firms. Steel and shipbuilding in particular, profited from

56 Mathews and Cho (2000) maintain that the initiative to plunge headlong into the electronics industry came from Lee Byung-Chull -the founder of Samsung. He decided in 1969 that Samsung was going to make its mark in consumer and industrial electronics (it did) and to achieve that the company needed to master LSI and later VLSI technology. The first step was an alliance with NEC and Sanyo to acquire some of the expertise. This provided Samsung with a foothold but was not enough for the firm to enter into the production of (VLSI) DRAMs. Fearing competition from Samsung, Japanese and American firms were unwilling to license the technology. In order to "leapfrog" Samsung was finally able to license 64K DRAM technology from Micron, which needed the cash. It also lured scores of semiconductor engineers from American firms by offering extraordinary salaries, bought equipment for fabricating DRAMs from multiple suppliers, and set up a functioning plant at Kiheung with the help of moonlighting Japanese engineers. Even though the market for DRAMs softened in the mid 1980s, Lee continued to press ahead with the next generation 256K DRAM and was ready to seize the initiative once the market rebounded.

57 Between 1983 and 1987, Samsung, Goldstar and Hyundai invested $1.9 billion in fabs and by 1987 were exporting $2 billion worth of VLSI circuits. Gereffi and Wyman (2016).

58 The relatively elastic supply of cheap capital could have played a key role in the buildup of both production and research capacity. See Brown et al (2017).

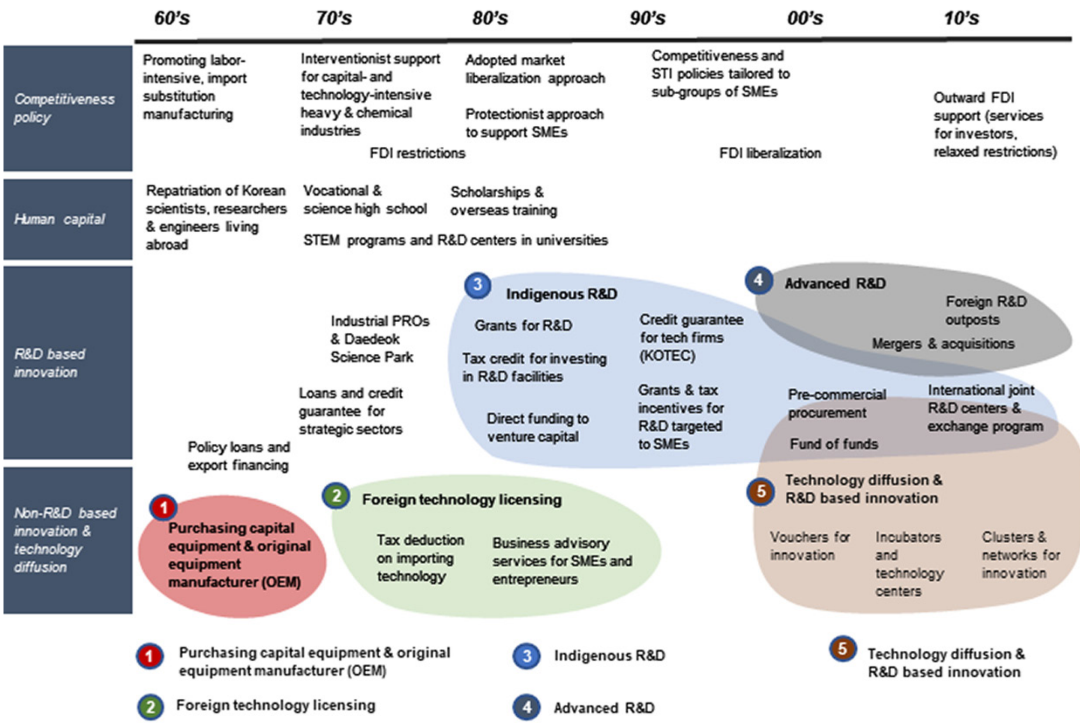
59 Chaebol that failed to heed the government's signals could soon lose their access to financing, their government contracts and worse still receive a visit from the tax authorities.

the instruction received by Korean workers in foreign facilities. Like their Japanese counterparts, the chaebol gave due attention to on-the-job training and flexibly deployed their workforce across different parts of the company so as to deepen skills and impart a better understanding of company operations; (ii) investment in R&D infrastructure initially focused on public research institutes that partially reversed the brain drain from Korea, trained local researchers and became a conduit for technology acquisition. Reverse engineering by the chaebol was followed by an increasing focus on product development and process improvement. And as industry waded into deeper waters, the chaebol expanded their applied research efforts so as to compete on equal terms with foreign competitors. Although the government continued providing guidance and support, the major conglomerates began displacing the GRIs and shouldering the bulk of R&D and the government centric ST&I strategy morphed into one in which the chaebol occupied center stage from the turn of the century (Figure 20); (iii) Given the importance attached to indigenizing technology, the chaebol licensed technology where possible, acquired foreign firms with the intellectual property they required to further than own capabilities, and entered into joint ventures with firms at the cutting edge that evinced a willingness to collaborate. OEM manufacturing and participating in global value chains especially for TVs and auto parts, accessed knowledge on design, production, styling, packaging, and quality control; and last but not least (iv) the chaebol served as the vehicles for operationalizing Korea's industrial policies and tapping the various sources of technical knowledge and integrating it into a commercially viable mass production system.

The entrepreneurial drive of chaebol leaders, the conglomerate structure, the marketing skills and the sheer commitment to become leading international manufacturers was ultimately responsible for keeping the export engine running smoothly for decades and reliably delivering productivity gains and unrivalled GDP growth. Moreover, the scale and scope of the activities of the leading chaebol enabled them to embark upon massive projects and to engage in the applied research needed to bring them to successful fruition. The chaebol also spawned the network of suppliers many owned or controlled[60] by the lead firms that underpinned the competitiveness of advanced manufacturing and increased the domestic share of value added. This supplier network was similar to the ones created by Japanese keiretsu.

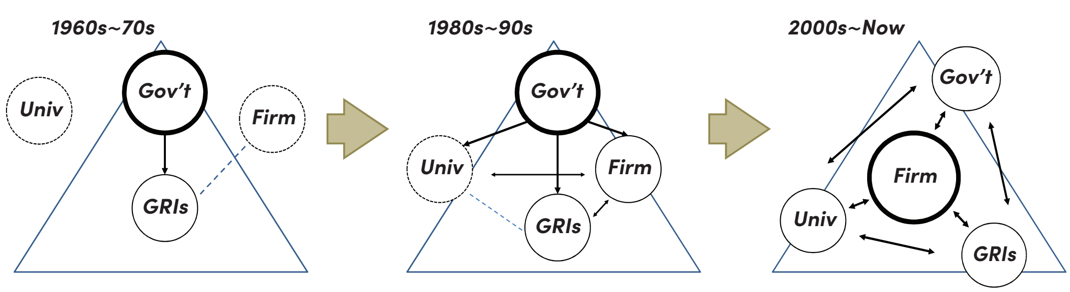
60 Ownership or control over firms linked to a chaebol was achieved through a web of cross shareholdings anchored to a holding company dominated by one of Korea's business families.

FIGURE 19. Policy initiatives responsible for Korea's technology development



Source: Frias (2022).

FIGURE 20. Dynamic structure of Korean innovation system



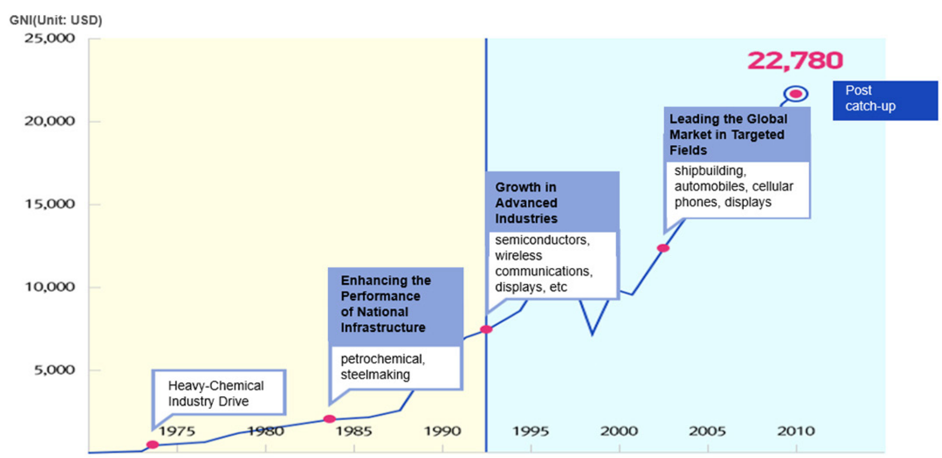
Note: The triangle in the figure denotes the innovation triangle. The three time periods are divided in line with the historical evolution of Korean innovation system.
Source: Shin, Hong, and Kang (2012).

ST&I strategy post 1997–98

For decades, it was applied and developmental research that was given primacy by the government and by the business sector, because it enabled Korea to diversify and maintain export led growth. However, following the shock administered by the East Asian Crisis of 1997–98, the government shifted gears recognizing that future economic performance was likely to be tied to industrial innovativeness and routinizing such innovation required foundational upstream research. Public spending on basic research by government and private research institutes was incentivized by grants and other measures; the chaebol were encouraged to engage more actively in upstream research in areas where they already enjoyed comparative advantage such as autos, cellular phones, memory chips, and telecommunications, and major universities that hitherto had taken a backseat, were also pushed to undertake more fundamental research and to collaborate with the business sector (Figure 20). The steady progression up the ladder of industrial complexity is shown in Figure 21 (Lee 2014).

The Korean government led all other OECD countries in its support for private sector R&D. Korea's direct and indirect support for business R&D was the fifth largest among OECD countries and leveraged a wider range of instruments than many OECD and developing countries (Figures 22&23), which served to increase private sector R&D from 2.3 percent of GDP in 2007 to 3.6 percent in 2017.[61] Korean business R&D was primarily conducted by large firms with SMEs responsible for a fifth well below the OECD average of one third (Jones and Lee 2018). By 2020, only Israel exceeded Korea's investment in R&D (4.81 percent of GDP).[62] Other European countries highly ranked on innovation indices, were spending a percentage point of GDP less (Figure 24).

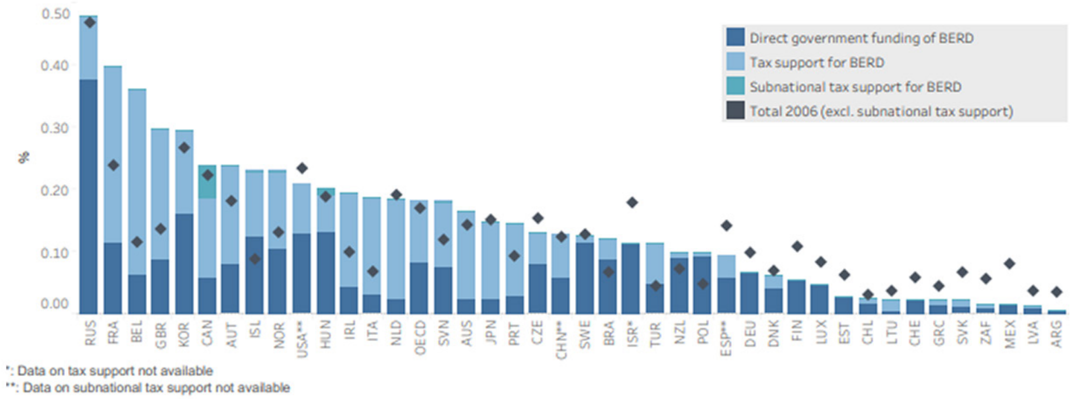
FIGURE 21. Korea's technological progress as a steppingstone for economic growth



Source: National Research Council of Science & Technology, Retrieved from https://www.nst.re.kr/nst/pr/04_01.jsp (Accessed 1 December, 2020).

61 OECD (2019) https://www.oecd.org/sti/rd-tax-stats-korea.pdf
62 WDI (2023) https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS

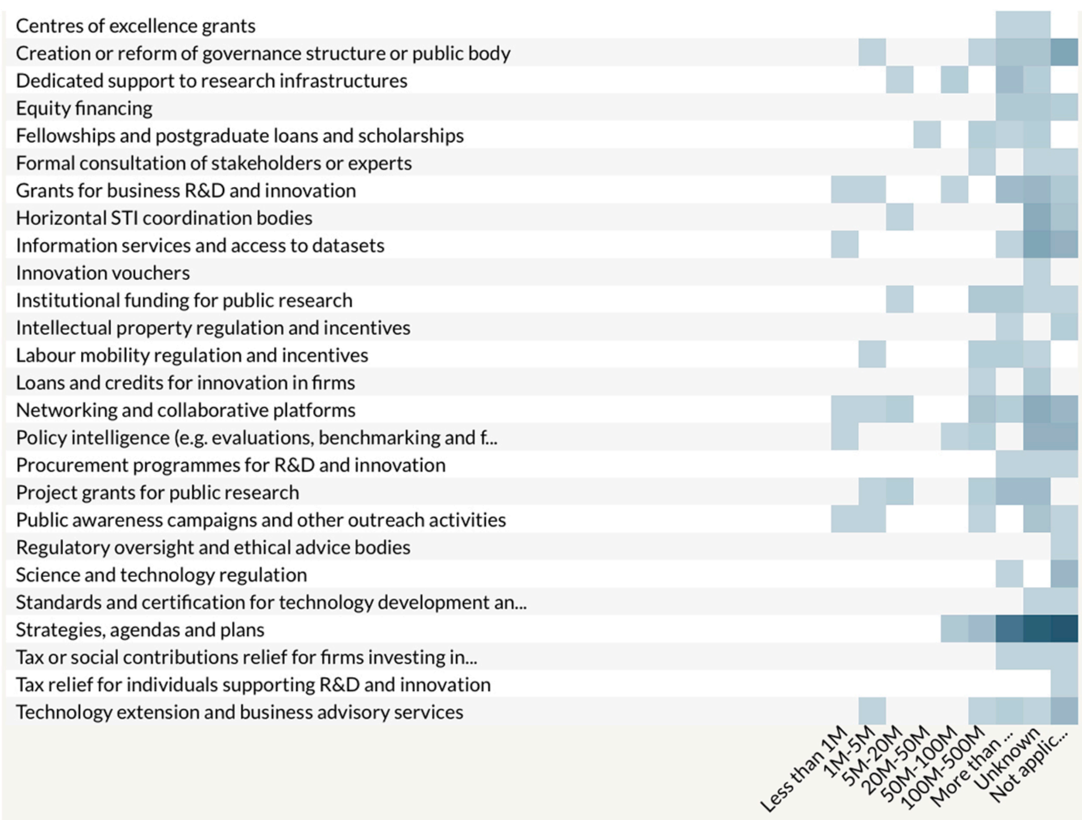
FIGURE 22. Direct government funding and government tax support for business R&D, 2017 and 2006



Data & notes: https://oe.cd/ds/rdtax

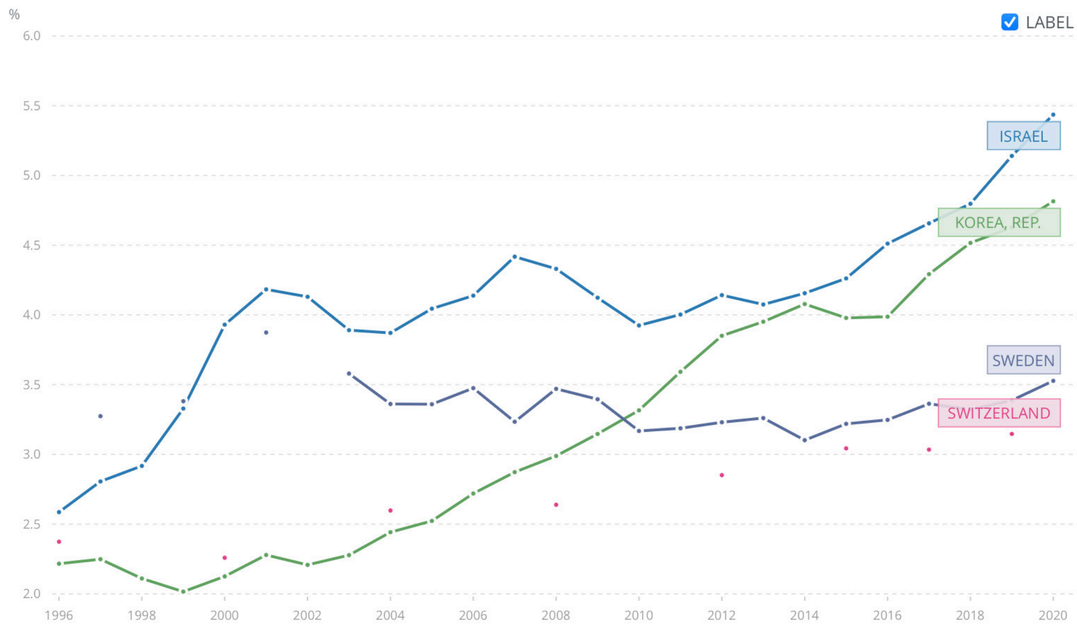
Source: OECD, R&D Tax Incentive Database. http://oe.cd/rdtax, June 2020.

FIGURE 23. Policy instruments utilized by Korean agencies to support ST&I



Source: OECD STIP Compass. https://stip.oecd.org/stip/interactive-dashboards/countries/SouthKorea

FIGURE 24. R&D investment in Korea, Sweden, Switzerland and Israel, as % of GDP, 1996–2018



Source: World Bank WDI (2023). https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=IL-KR-SE-CH

Through the 1990s, MOST (later the Ministry of Education, Science and Technology and currently the Ministry of Science and ICT) and the Ministry of Knowledge Economy were the public agencies working with private firms to guide research (Nature 2020a). The Five-Year S&T Principal Plan and the National R&D Program managed by MOST launched funds to support research on for example, space vehicles and satellites and bioscience. Fifty-seven research centers received grants to finance research, which would enhance Korea's industrial competitiveness. This was bolstered by the Creative Research Initiative in 1997, the National Technology Roadmap and the 21st Century Frontier R&D Program in 1999, the Biotech 2000 Plan, and by the Nanotechnology Development Plan in 2001. This has been superseded by the Creative Material Development Program. Anticipating the role that ICT would play, the government embarked on $1.5 billion program to build a broadband infrastructure network starting in the late 1990s. This belief in the innovativeness of a data driven economy has continued to this day with the government moving forward with 5G commercialization.

As the center of gravity of Korea's research shifted from the public to the private sector, the government sought to strengthen the linkages between GRIs, and industry researchers and it worked with the corporate sector to build innovation centers for example in Gyeonggi near Seoul and with lesser success in other parts of the country.[63] With the major conglomerates focusing on

63 "By 2010, South Korea had 105 regional innovation centers and 18 techno-parks, as well as 7 federal programs to strengthen the competitiveness of industrial cluster programs…Although government funding continued to promote R&D spending and programs to boost translational development and scientific, engineering and managerial expertise, the weight of major investment in R&D shifted to the corporate sector in search of patents and profits." Dayton (2020).

applied research and product development, the government began giving more attention to basic and fundamental research that could eventually underpin disruptive innovation.[64] This was the start of the Big Science programs, in particular the 577 program, the purpose of which was to take Korea to the technological frontier in seven major fields: these included the auto and electronics technologies as well as the space program and nuclear development (UNESCO 2015). The founding of the Institute for Basic Science (a network of multiple centers) in 2011 was one outcome (Nature 2020b). Increased collaboration with international scientific agencies was a second although it is off to a slow start with Korea having "one of the lowest levels of international collaboration in science and innovation among OECD countries, with 3.4% of patents involving co-invention, and 26.4% of scientific publications involving international co-authorship."[65] However, collaboration with Chinese institutions has been productive.[66] Attracting talent from abroad is third, which has begun yielding fruit.[67]

In keeping with past practice, the government in 2010, tabled a Long-Term Vision for Science and Technology Development and a Future Vision for S&T: Towards 2040. Other Basic Plans have followed in 2013 and in 2018 and the Future Vision was updated in 2017 to remove mention of nuclear energy from the list of targeted technologies, however this has since been reinstated by the Yoon Administration (UNESCO 2021). The Fourth Basic Plan stresses advances in S&T that give rise to new industries and jobs and that improve the quality of life, creating an ecosystem that is conducive to innovation, building the capacity to tackle challenges to come, and innovation that strengthens the competitiveness of SMEs helped by grants from the Korea Small Business Innovation Research (KOSBIR; UNESCO 2021). Through the Korean New Deal, the government according to the OECD (2020), seeks "to revive the economy by facilitating the convergence of new and old industries through enhanced use of digitalization. The New Deal focuses on projects exploiting synergies between the government and the business sector, including strengthening data infrastructures, expanding data collection and usage, establishing 5G network infrastructure early and developing artificial intelligence. The New Deal also includes measures aimed at greening the economy and reinforcing the social safety net."

64 The importance attached to basic science has not flagged. Korea sees that as the only way it can become a leader after decades of being viewed as a fast follower. Nature (2020b)

65 OECD (2017a). International collaboration is hampered by a number of factors. "Korean research institutes and universities are known for signing large numbers of MOUs with institutions around the world and engaging in signing ceremonies that look good in pictures on the website but have relatively little significance. The lack of follow-up concerning these signings and failure to establish a clear office with responsibility for future international collaborations often [yields] limited results. [The] Korean government requires that institutes and laboratories be frequently evaluated. Rarely are laboratories allowed to simply dedicate themselves to research for a block of time. There are no five-year research grants and frequent progress reports are required. Most grants require so much paperwork for every trip or purchase that keeping track of the paperwork is a full-time job. Another obstacle to international collaboration is the low salaries paid to the supporting staff in most research institutes… It is difficult to recruit staff with a strong command of English, or a background in science. The lack of staff with training in English means that researchers must do all of their work themselves when using English. The…lack of institutional support forces researchers to be far more cautious in their international exchanges, limiting themselves to interactions that they can handle with their own time." Biotech Policy Research Center (2009).

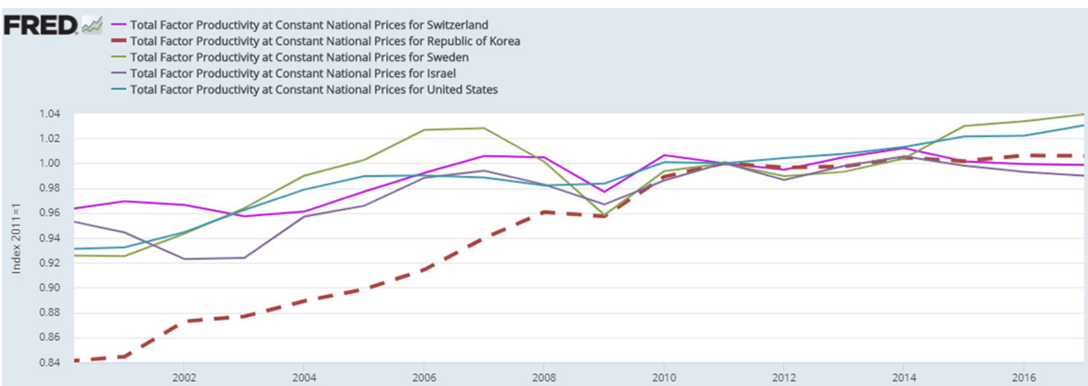
66 *Nature* (2020). 'A new deal for South Korea Science.' https://www.nature.com/articles/d41586-020-01463-w

67 *Nature* (2020). 'South Korean institutions lure global talent.' https://www.nature.com/articles/d41586-020-01467-6

Less than perfect

A rethinking STI strategy has been ongoing for a few years as Korea's growth has slowed and competitive pressure from China has mounted.[68] Several weaknesses and concerns have surfaced, which can inform strategies of other developing countries. One is the persisting gap between productivity in Korea and the OECD average even though a few industries such as electronics, metals and chemicals, exceed the OECD average. Second, the pace of convergence is slowing. Korea's spending on R&D and the trend in Korea's total factor productivity have diverged. The former has trended upwards, while TFP, after fast catch-up with the global leaders between 2000–2010, has since stagnated relative to the US and fallen behind peers such as Sweden (Figure 25).[69] Third, technology adoption by SMEs—the vast majority of firms—has lagged and their productivity falls far short of that of leading firms (Jones and Lee 2018). For this reason and because older workers lack digital skills, wage inequality is the highest among OECD countries.[70]

FIGURE 25. Total factor productivity at constant national prices for Korea, Sweden, Switzerland, Israel, and USA, 2000–2018



Source: https://fred.stlouisfed.org/series/RTFPNACHA632NRUG#0

Fourth, although Korea invests heavily in research, the innovation system remains relatively inward looking, which may account for the meager productivity gains. Amongst the OECD countries, Korean firms large and small collaborate the least with companies from other countries in the sphere of innovation and on balance, there is much scope for increasing international collaboration by Korean researchers. Only a few domestic research programs are open to international participation, although the government has introduced incentives for researchers to join international research

68 An initial round of rethinking began after the East Asian Crisis in 1997–8. Kang (1998); Seong et al (2005).

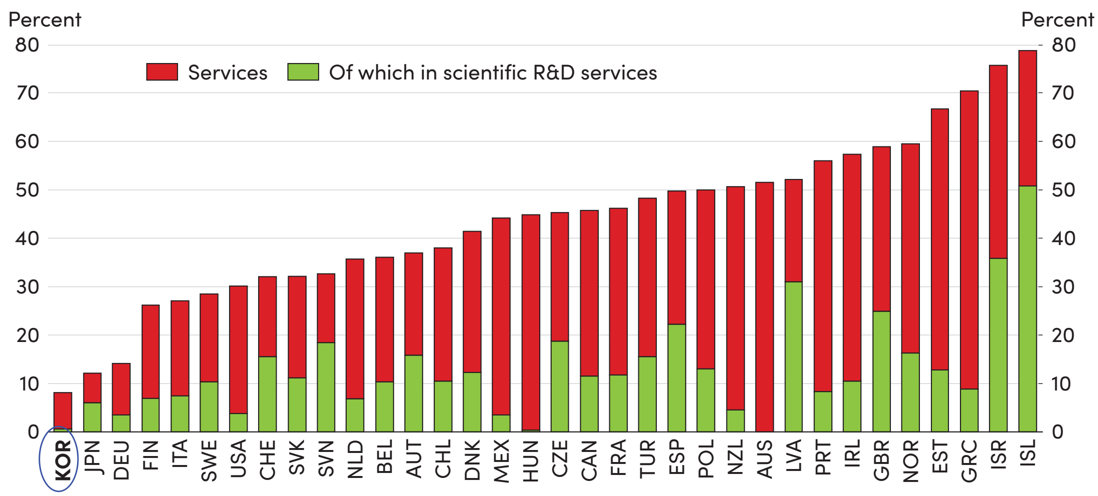
69 https://koreajoongangdaily.joins.com/news/article/article.aspx?aid=3073121; http://www.koreaherald.com/view.php?ud=20200504000510; Between 2011 and 2021, Taiwan's TFP growth has also outpaced Korea's. Conference Board (2022).

70 https://oecdecoscope.blog/2020/08/11/korea-roadmap-to-narrow-digital-gaps/

programs, including those funded by the European Union Horizon 2020 program and various agencies in the US.[71]

Fifth, Korea's productivity deficit is most noticeable in tradable services that are likely to figure more prominently in future exports. It devotes less to R&D in services than any other country in the OECD (Figure 26). Korea continues to rely on exports of a narrow range of high and medium tech manufactured products. Integrated circuits, cars, refined petroleum, vehicle parts, and ships, accounted for almost a third of the total in 2020.[72] These are now exposed to intense competition from China and producers elsewhere. Diversification and innovation are more urgent than ever.

FIGURE 26. R&D in services, 2015



Source: OECD 2018 (slide 32).

STI strategy under the Moon Administration, took a somewhat different tack. It prioritized the role of SMEs and attempting to improve their labor productivity (Figure 27). "Bottom up" spending by the National Research Foundation (NRF) the principal government funding agency absorbed a major slice of its more than $1 billion of total distribution. This plus a raft of incentives (e.g., R&D tax incentives, loans for innovation, credit guarantees for innovation, early-stage equity finance and public procurement for innovation) attempted to transform the SME sector and bring its productivity closer to that of the leading firms by accelerating the diffusion of digital technology and encouraging start-up activity in areas such as biotech. By the end of 2020, there were close to 20,000 factories owned by large and mid-sized companies that had adopted smart manufacturing techniques.[73]

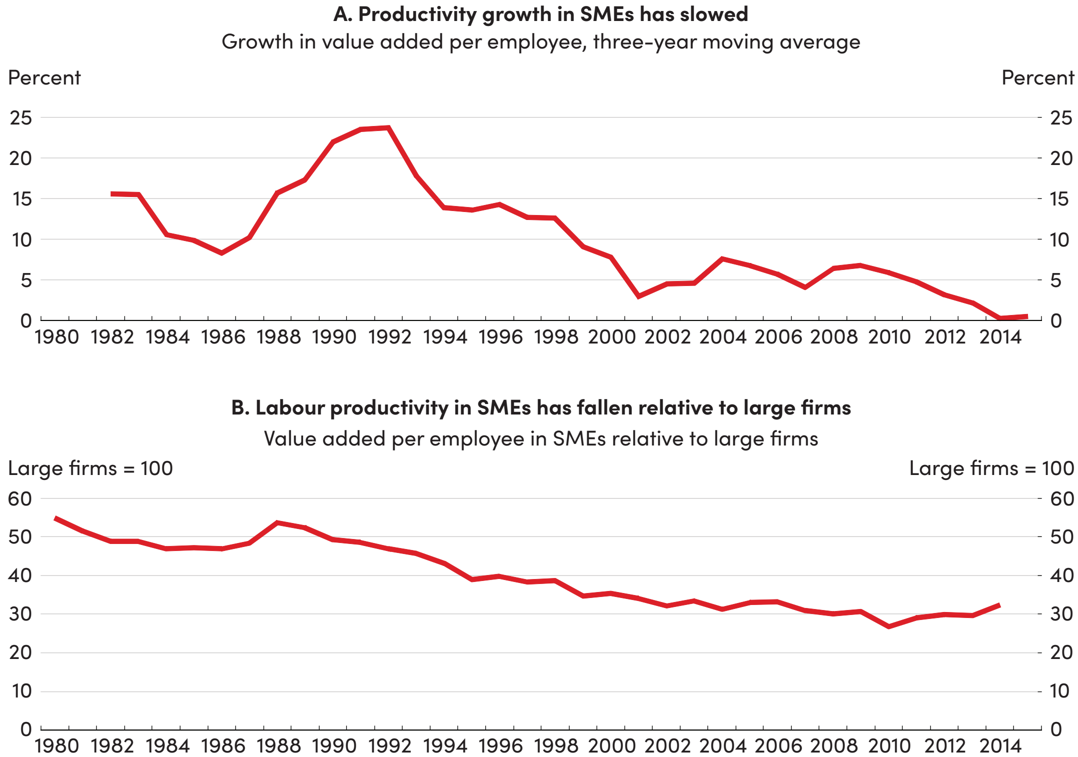
71 Korean companies can now participate in research consortia that bid in the EU Horizon 2020 R&D programs: https://ec.europa.eu/research/iscp/index.cfm?amp;pg=korea. A bilateral partnership to cooperate with the US on S&T was initiated in 2019. https://www.dhs.gov/science-and-technology/news/2019/10/24/news-release-us-rok-partner-science-technology-rd

72 https://oec.world/en/profile/country/kor

73 http://koreabizwire.com/smart-factories-rise-sharply-nearing-20000/179474

In order to sidestep Korea's restrictive regulations, the government has made much use of regulatory sandboxes that permit experimentation and prototyping sheltered from regulatory intrusion.

FIGURE 27. Labor productivity in SMEs relative to large firms



Source: Jones and Lee (2018).

Among the goals announced by the Yoon Administration (in 2022) is the "creation of a dynamic economy led by the private sector and backed by the government".[74] The top-down approach continues alongside. Its efficacy was recently demonstrated by the speed with which Korean researchers and manufacturers could produce and distribute Covid testing kits and PPE and the launch of a satellite to measure air pollution over the Pacific.[75] The big-ticket research now includes Electric Vehicles (EVs), Autonomous Vehicles (AVs), advanced semiconductors and the technology to make the 4th IR a reality with the use of 5G now available nationwide.

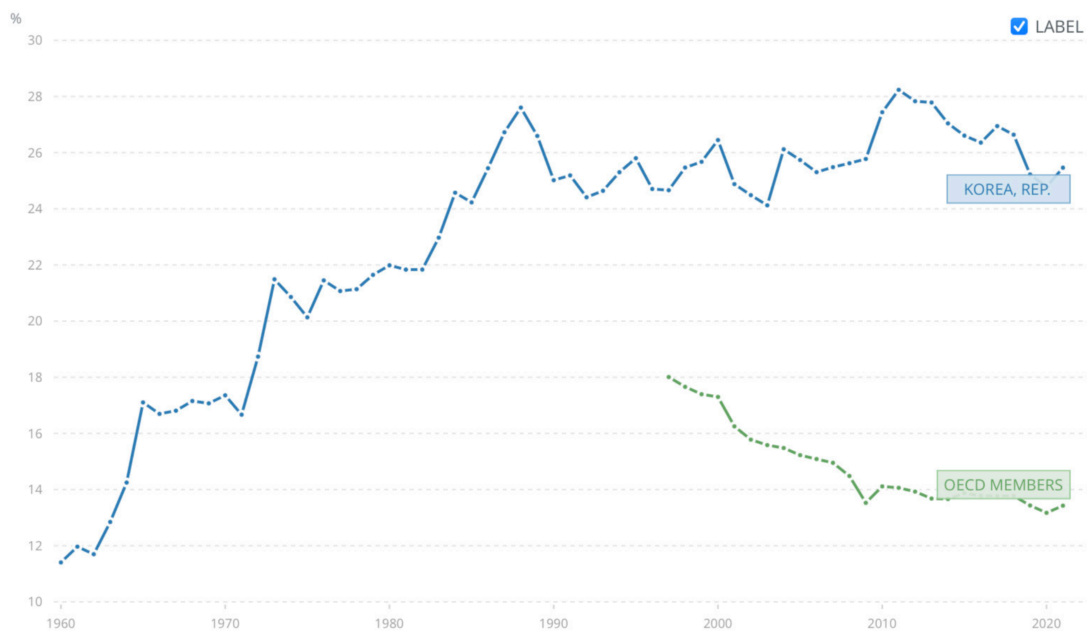
Korea's STI system has yielded rich dividends because industrial and S&T policies were interwoven and mutually reinforcing. To get the maximum mileage from their investment in R&D, African countries might consider adopting an approach that meshes ST&I policies with policies aimed at developing industry and services.

74 https://www.korea.net/NewsFocus/policies/view?articleId=218607
75 *Nature* (2020). 'Boosting Korea's basic research.' https://www.nature.com/articles/d41586-020-01464-9

4. Korean lessons for African countries

From the 1960s onwards, manufacturing industry has anchored Korea's development. It was the principal source of productivity gains and except during the past decade, the well from which most innovations emerged. R&D policies and expenditures intermeshed with industrial policies. The bulk of research supported and advanced the fortunes of manufacturing industries. Close to two thirds of research in other industrialized countries also serviced the industrial sector however, until recently Korea was an outlier. Because of its salience in the economy, manufacturing absorbed a larger share of the expenditure on research. Moreover, in order to maintain their competitiveness, the chaebols have been compelled to ratchet up their R&D investment to offset the declining productivity of research activity. The composition of research is changing gradually because of an increasing focus on digital technologies favoring services nevertheless, the Korean economy remains far more rooted to manufacturing than the OECD average (Figure 28). In the foreseeable future, Korea's R&D will remain oriented towards medium and high-tech manufacturing industry.

FIGURE 28. Manufacturing value added in Korea, OECD countries



Source: WDI. https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=KR-OE-XP

This history and likely future trends color and shape the lessons late starters can draw from Korea's experience because for most if not all developing countries, there is "trouble in the making" (World Bank 2017). Industrialization and ST&I developments closely mimicking those adopted by Korea may not be in the cards for most African countries. Hence the interest in Industries without Smokestacks (i.e., services and agribusinesses. Page 2020; Newfarmer et al 2018). Automation is likely to drag down the already low share of manufacturing and constrain its economic significance. Thus, the borrowing from Korea's ST&I strategy must necessarily be selective. Very likely, the enabling developmental, trade and technological opportunities for countries in SSA in the third and fourth decades of the 21st century will be very different from those that benefitted Korea, other Tiger economies and China in the last quarter of the 20th century. Nevertheless, Korea's experience can be a valuable guide.

There are six key lessons for economies in SSA:

1. **Get the basics right.** None of the SSA countries is likely to succeed in emulating Korea or any other countries that have risen out of poverty without first building up basic infrastructure, including access to electricity, roads and the internet, investing in skills, sustaining macroeconomic stability, promoting access to finance and improving the business environment. Technology absorption and innovation is necessary, but not a sufficient condition to promote development. It needs to be built on the overall foundation that is conducive to growth. Much has already been achieved, including during the past decade, but much more remains to be done.
2. **ST&I capabilities should mostly focus on technology absorption by firms.** ST&I capabilities need to support and advance a long-term development strategy. Research/knowledge capital has a high opportunity cost and must be efficiently utilized. It should generate returns comparable to those a developing economy, where both knowledge and physical capital are scarce, would derive from other productive activities. No country can afford to engage in reinventing the wheel or devoting resources to costly high-tech endeavors because high tech is the flavor of the day. Thus, research on AI and in nanotechnology would be a little misplaced in the African context—whereas utilization of digital technology to develop Fintech and e-commerce for example, is more likely to be rewarding. Productive research is an expensive undertaking; therefore, countries must choose wisely. Korea's industrial strategy targeted industrial diversification first into complex medium tech products and very soon thereafter, into high tech DRAMs and consumer electronic products. The principal objective of research activity through the 1990s was to absorb from abroad and to disseminate industrial technology to accelerate diversification into targeted industries. Government research institutes established the research base and as private companies grew and their revenues expanded, they complemented the research by the GRIs and customized the research to suit their own purposes. In other words, a state guided industrial strategy necessitated the creation of supporting research infrastructure with the state initially taking the lead and laying the foundations. Large private firms quickly built on those foundations. The state's role, its financial support and procurement policies were catalytic. They eased the burden of risks weighing on private firms and were responsible for the early and effective participation of the private sector that needed the research inputs in order grow and diversify its exports. Much of the research conducted during the first three decades of Korea's industrialization was applied, downstream research taking advantage of existing technologies to improve productive efficiency, to branch out into new product

lines and to incrementally innovate. This was the right approach; it yielded substantial dividends and is suited to the current needs and capabilities of African countries although unlike Korea, they would be directing more of their research effort into agriculture and services, including health services, and allocating fewer resources to research related to manufacturing, which can be readily sourced from abroad. What African countries need are coherent long term standalone STI strategies that extend beyond the nuts and bolts of R&D to embrace the multidimensional nature of innovation in an African context.

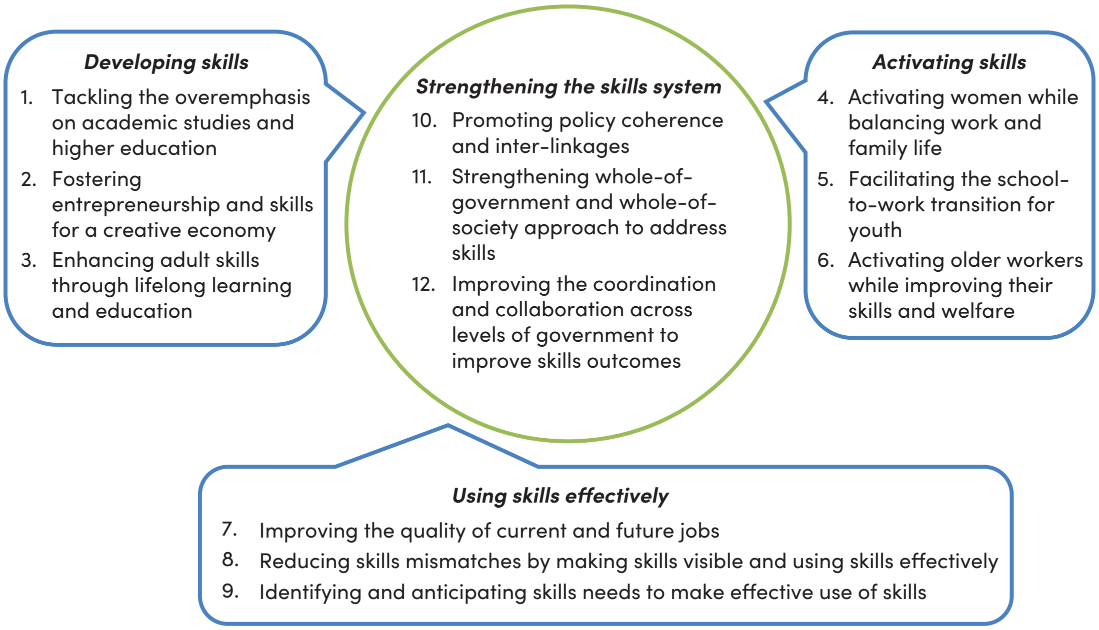
3. **Research output and its quality is largely a function of human capital inputs.**[76]
The success of Korea's industrial and technology policies rested on the parallel accumulation of workforce skills (Suh and Derek 2007). The education and training systems were built with great rapidity from the ground up starting with primary education and extending to tertiary level and vocational institutions. The quality of primary and secondary education was critical.[77] It was achieved through teacher selection and motivation, long schooldays, low dropout rates, and high expenditures on facilities textbooks and extra tutoring two thirds borne by students. In the late 1960s total education expenditures amounted to nearly 9 percent of GDP. By 1990, they had risen to 11 percent with the state investing about 4 percent of GDP (Lee, J, W., 2013). The quality of tertiary level skills was improved through cooperative arrangements with and borrowing from leading foreign universities (mainly in the US). Scholarships provided by the government and by foreign donors enabled thousands of Koreans to obtain advanced degrees from western and Japanese universities—and most of these students returned to take up employment in Korea as there were ample opportunities in the business sector and research institutes offered handsome salaries to those with specialized skills. Korean universities unlike universities in Switzerland and Sweden did not do much research or provide technical support to private firms. They concentrated on teaching, which was an advantage so long as basic research was not a priority and would be the appropriate policy for most universities in African countries although a small number of large public universities could fruitfully engage in research and establish linkages with industry. In order to make up for skill gaps in industry and its research facilities, Korea drew upon the expertise of equipment suppliers, foreign consultants, research entities, and international organizations and used exchange programs to upgrade the technical and language capabilities of the workforce. Vocational training was not neglected as it complemented the assimilation of technology by industry. Attaining the desired results was (and remains) a challenge as it has proven to be in other countries, however, almost a third of tertiary level students now enroll in

76 In their comprehensive review of policies to promote innovation, Bloom, van Reenen and Williams (2019) note that "increasing the quantity of innovative activity requires increasing the supply of workers with the human capital needed to carry out research … [through] expanded university programs…. [more] STEM majors … and a [lowering] barriers to talented people becoming inventors in the first place."

77 The relationship between education quality and growth has been underscored by the research of Hanushek and Woessmann (2007).

junior or polytechnic colleges (Figure 29).[78] This approach is of relevance for countries in SSA some of which are taking steps in this direction, but gross tertiary enrollment in SSA was 9.4 percent in 2020 far below the global average of 38 percent, with plenty of room for improvement.[79]

FIGURE 29. Skills challenges and enabling conditions for Korea



Source: OECD (2015).

4. **A thriving private sector, including large firms, is necessary to productively leverage investment in research.** Countries need firms that will work with GRIs (and universities) to assimilate knowledge and to innovate. A World Bank study by Ciani et al (2020) underscores the contribution of large firms to technological change, net job creation, labor

78 OECD (2009); Lee et al (2019). "Public vocational training focused on securing the supply of skilled workers in the heavy and chemical industries, as well as other national key industries and export industries. In addition, private sector involvement was actively promoted in offering trainings to their employees as well as in establishing the support system. Thus, over the industrialization period from 1962 to 1997, the total number of vocational trainees was 2.5 million, with about 60% of the trainees receiving on-the-job in-plant trainings.... Current training system in Korea is classified into three categories—vocational training for the employed, vocational training for the unemployed and public training for strategic industries. Various programs are implemented to increase training opportunities, expand the training market to private providers, and provide financial support to SMEs."

79 Yusuf et al (2009) ibid; Gangwar and Bassett (2020); Oxford HR (2021) https://oxfordhr.co.uk/2021/06/29/higher-education-in-sub-saharan-africa-challenges-and-prospects-salah-khaled/; There is need for "Broader investment in TVET resources, an intensified push for meaningful completion of TVET (i.e., meaningful qualifications), strengthened practice orientation of TVET, extended TVET-teacher education, increased networking of TVET providers including experts from industry and business, as well as greater attention to—and involvement with—the informal sector (informal work, informal TVET). With regard to TVET providers, greater emphasis on the more effective use of ICT in teaching and learning is demanded; it is clear that such use of ICT would also require a revision of existing TVET programs". Habler et al (2020).

productivity and exports. In all the countries included in the sample, the top performers were large firms, and it is firms employing more than 300 workers that are systematically underrepresented in many developing countries. As noted earlier, Korean chaebol shoulder two thirds or more of the research expenditure, conduct most of the downstream research and some basic research as well. This research is being supplemented by start-ups a few of which have morphed into fast growing gazelles, but the research base load continues to be borne by large firms. Two factors have contributed to the high volume of research conducted by Korean firms. One is the size and export orientation of the chaebol. Only they have the deep pockets, access to market financing[80] and the incentive to engage in R&D on such scale (and invest in expensive production facilities e.g., for fabricating semiconductors) because without it they would be out competed by foreign rivals. A second factor as noted above is the chaebol focus on manufactures. The pivotal role that firms play deserves the greatest emphasis. In order for research to achieve a critical mass, a country needs large firms that will promote in-house and external R&D to assimilate knowledge and to innovate. The large firms that are more likely to undertake R&D on any scale will be manufacturing firms that are exporters. This may change as digital technology continues making inroads. One of the weaknesses of countries in SSA is that they have few large firms or have large firms that are providers of services or that do some manufacturing but only serve the domestic market. Such firms will rarely expand the scope and level of research beyond what is conducted by public research institutes. Consequently, little if any benefit will accrue from public sector research in terms of productivity gains, innovation or GDP growth. The importance of large firms has been demonstrated by their superior ability to weather the Covid pandemic and to spearhead Korea's economic recovery through the export of semiconductors, IT equipment, general machinery, and automobiles—all manufactured by chaebol.[81] They are also leading the recovery in other EMDEs. Local entrepreneurship with government assistance was responsible for the emergence and growth of Korean chaebol. This is also one of the ways by which other countries have populated the top tier of the business sector (e.g., in Malaysia, Indonesia and the Philippines). Some large firms are the affiliates of MNCs, others are spin offs of existing enterprises or are state owned enterprises. There is no formula that can be used to guide infallible policies. Most African countries could benefit from FDI and joint ventures as these can help establish firms of the desired size and also serve as a conduit for technology transfer. Encouraging local entrepreneurship by crafting the policy and institutional environment that can accelerate the growth of larger and promising start-ups is also supported by research. One characteristic shared by bigger firms is that they were

80 As noted earlier, in the early stages, the chaebol could bank on subsidized loans from public financial institutions and from state controlled commercial banks. From the late 1980s onwards, following financial liberalization, the chaebol grew less dependent on policy loans and acquired more influence over the banking system. Lee, Lee, and Lee (2002); Cho (1989).

81 http://www.businesskorea.co.kr/news/articleView.html?idxno=52701; https://www.bloomberg.com/news/articles/2021-01-01/south-korea-s-export-growth-in-december-at-fastest-since-2018; https://www.wsj.com/articles/south-korea-demonstrates-asias-economic-resilience-to-pandemic-11611664966

relatively large from the very outset—from the start-up stage—and their rapid ascent is partly explained by this factor (Goswami, Medvedev and Olafsen 2019).

5. **A related lesson is the desirability of an environment, which is conducive to the emergence of 'high growth firms'—the future unicorns.** Such firms serve as a conduit for new technology, can bring innovations to the market, "are powerful engines of job output growth…and positive spillovers" and a source of exports (Goswami et al 2019; Audretsch 2012). They would also boost total factor productivity. This is Korea's current focus and appropriate for SSA countries as well (Yusuf 2022).
6. **Harnessing digital technologies could kickstart innovation.** Korean government initiative to invest in and continually upgrade ICT infrastructure, to provide easy, affordable access to high-speed broad band Internet connections, to support computer/IT literacy, and to encourage the diffusion of digital technologies has supported industrial productivity and is promoting innovation in the services sector (OECD/World Bank Institute 2000). To develop the ICT based information society, the Korean government relied on four master plans: the Informatization Promotion Act (1996) and the first Master Plan for Informatization Promotion (1996); Cyber Korea 21 (1998); and the e-Korea Vision 2007 (2003).[82] This kickstarted investment in the physical services and affiliated services with the result that by 2003, ICT emerged as the leading growth engine. Korean exports of digital services are on the increase, several unicorns offering innovative services have appeared, and digital technologies could in time boost the productivity of the services sector as a whole. Governments in SSA can take the lead with or without supporting foreign investment in expanding the ICT infrastructure and putting in place appropriate regulations, which can catalyze start-up activity—as is occurring in Kenya and Nigeria for example.[83] Given the rapidity with which digital technologies are spreading, all African countries need to take the needed steps to make high speed broadband widely accessible,[84] to encourage adoption of technologies, to build tech literacy, assist start-ups take advantage of digital technology

82 Other actions included the Informatization Promotion Fund and the e-Government Vision and Strategy. Karippacheril et al eds. (2016).

83 Hjort and Poulsen (2019) have found that the access to fast Internet in African countries has led to an increase in employment, entry of firms and exports. The arrival of fast Internet and employment in Africa. Mobile broadband has also helped raise consumption of households in Nigeria and reduce poverty. Bahia et al (2020). A World Bank diagnostic of Nigeria's digital economy (2019) sees some encouraging developments but also lengthy future agenda for the authorities and the business community. "Lagos is a mature and active ecosystem with dynamic incubators, venture capital companies, and digital start-ups. Digital entrepreneurship ecosystems are also growing in the cities of Abuja and Port Harcourt, with a potential for expansion to other cities. Although urban Small and Medium Enterprises (SMEs) are increasingly using digital platforms for trading, digitalization of firms in traditional industries and rural locations remains limited. Larger firms are more actively using digital technology for basic business purposes, such as communication with customers, but more advanced uses of technology also remain limited." http://documents1.worldbank.org/curated/en/387871574812599817/pdf/Nigeria-Digital-Economy-Diagnostic-Report.pdf; Other research on the benefits derived from mobile telephony conducted in India found that farmers who could access advice on new seed varieties, the use of complementary inputs and associated farming practices via their cell phones increased their crop yields by 25 percent over neighbors who lacked such access. Gupta, Ponticelli and Tesei (2020).

84 Only a third of African cities are within 6 miles of a high-speed fiber optic network and only a quarter of rural dwellers have internet access. Moreover, just 17 percent of the population of SSA can afford 1 GB of data in a month vs. 47 percent in Asia. Harrison and Pezzini (2021).

(only 31 percent of formal sector firms in Africa have a website vs. 39 percent in Asia), and to narrow the digital divide. "ICTs [can] play a key role in innovation by creating business opportunities, supporting the modernization of the economic system, reducing poverty, and generating opportunities for social and economic inclusion. Mobile phones are also a starting point for digital literacy. Therefore, affordable and accessible mobile networks and services are a key element for STI-led development."[85] Whether this alone will result in near double-digit rates of growth is unlikely given the experience of Korea and other advanced countries over the past two decades, however, countries that do not take advantage of digital technologies will find that the gap between them and high-income countries will only widen.[86]

85 UNCTAD (2020) https://unctad.org/system/files/official-document/dtlstict2020d4_en.pdf

86 Harrison and Pezzini (2021) also make the case for regionally coordinated action. "Policymakers must coordinate at the regional and continental levels. National digitalization strategies cannot work in silos. Integrating the continent's digitalized economies in the African Continental Free Trade Area calls for supranational cooperation in areas including digital taxation, data security, privacy standards, cross-border data flows, and interoperability. As of today, only 28 African countries have personal data-protection legislation in place, and just 11 have adopted substantive laws on cybercrime. These countries should share their experiences and lessons learned with the rest of the continent." OECD (2019); and OECD (2021).

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