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Technological Capability and Industrialisation in Africa

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Background

Anecdotal and empirical evidence suggests that countries that have managed to sustain economic growth, create more and better jobs, and pull themselves out of poverty are those that can industrialise. Therefore, how countries in Africa can successfully industrialise remains a priority on the region's development agenda.

Starting from the work of Gerschenkron (1962) and Abramovitz (1986), long-standing literature has established that capability building is the essential prerequisite for successful industrialisation and catch-up. Lall (1992) makes a specific case in this regard for technological capability, while Kim (1997) associates South Korea's industrialisation with the accumulation of technological capability. Ertur and Koch (2007) provide empirical evidence for the spatial benefit of technological capability, as a country's accumulation of technological capability benefits both the country and its neighbours. Despite this, we know little about how technological capability affects industrialisation in Africa. We fill this knowledge gap in our recent paper (Mensah and Ndubuisi, forthcoming).

The recent diffusion and rapid adoption of digital technologies, infrastructure development, increases in human capital, and technology import have broadened the scope of economic activities in Africa (Choi *et al.*, 2020; Ndubuisi *et al.*, 2021). In addition, it has been demonstrated that sub-Saharan Africa (SSA) as a whole is currently going through a manufacturing (re)naissance, as evident from increases in the manufacturing employment share of the average African economy, which

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started happening around 2010 after a protracted period of subpar industrial performance (Kruse et al. 2022). Is technological capability related to the recent patterns of manufacturing in Africa? Our recent paper provides an answer to this question.

First, our paper proposes a unified analytical technology capability framework that is used to build a novel technological capability index for 50 African countries for the period 2000 to 2018. Second, it uses this technological capability indicator in a spatial econometrics model to examine how industrialisation in an African country depends on the country's technological capability and the technological capability and industrialisation of other African countries.

Technological capability: Conceptualisation and operationalisation

There is a plethora of analytical frameworks for technological capability (e.g., see Archibugi and Coco 2005; Desai et al. 2022; Filippetti and Peyrache 2011; Wagner et al. 2004). Rather than add to this list, we propose a unified analytical framework that is based on mapping the commonalities among existing frameworks, with a little update to reflect Africa's technological circumstances (see Figure 1). Our mapping and update resulted in four dimensions of technological capability: technology precondition, technology infrastructure, technology import, and technology effort.

Technology precondition is the bedrock of technological capability, as it is the *conditio sine qua non* to produce, adopt, absorb, retain and recombine technology. Technology infrastructure refers to soft and hard infrastructures that engender the production of, access to, and diffusion and exchange of technology. Soft infrastructure refers to institutions and enabling frameworks that incentive and govern technology exchange. Hard infrastructure, on the other hand, refers to public hardware (and to some extent private hardware such as personal computers) that are largely associated with the production, access, and diffusion of technology. Technology import refers to knowledge and technology that are sourced from abroad; technological efforts are direct technology activities or achievements.

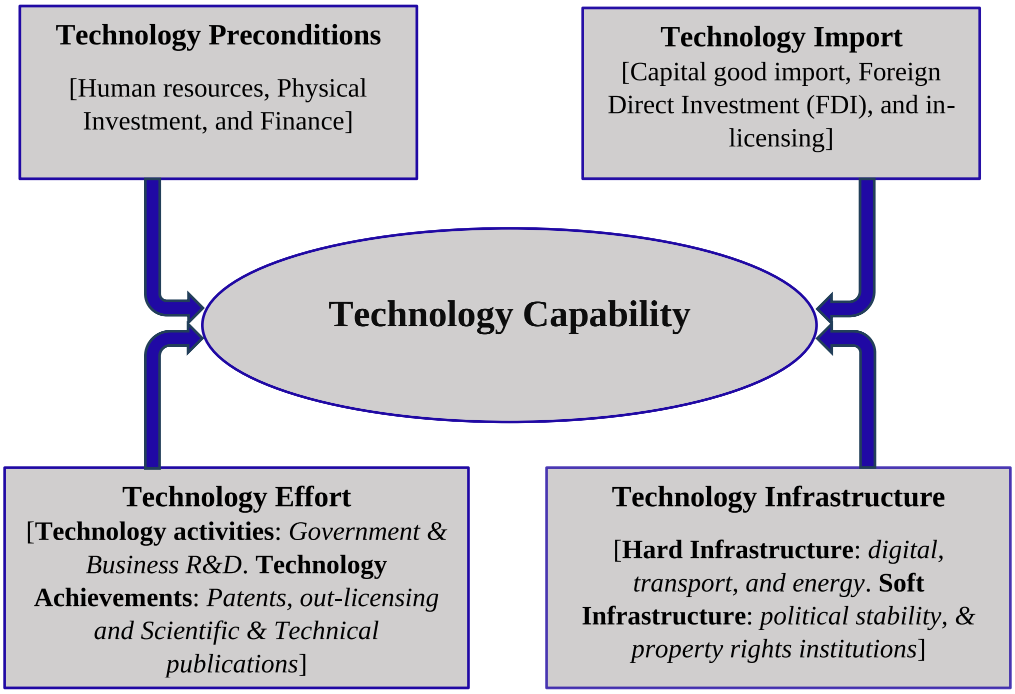

Figure 1. *A unified technological capability framework*

Table 1 shows the variables we considered while operationalising it. These variables were determined by data availability. We proceeded through four steps to arrive at the technological capability index. First, we standardised the variables to have a mean value of zero and a unit standard deviation. Second, the variables contained in each subcomponent were reduced into a single index by employing principal component analysis – a widely used approach of transforming sets of indicators into a smaller set of linear factors. Third, we reapplied the principal component analysis to the four composite indexes generated. Fourth, we normalised the resulting index to range from 0 to 100, with higher values indicating higher levels of capability.

Table 1. *Operationalising technological capability*

Subcomponents (1)	Subcomponents (2)	Variables	Data sources
Technology precondition		Domestic credit to private sector by banks (% GDP)	World Development Indicators
		Human capital	UNCTAD Statistical Database
		Gross fixed capital formation (% GDP)	UNCTAD Statistical Database
Technology infrastructure	**Hard infrastructure**	Transport infrastructure	UNCTAD Statistical Database
		Energy infrastructure	UNCTAD Statistical Database
		ICT infrastructure	UNCTAD Statistical Database
	Soft infrastructure	Institution	UNCTAD Statistical Database
		Rule of law	World Governance Indicator
Technology import		Capital good import	BACI-CEPII
		Foreign direct investment inflow (% GDP)	UNCTAD Statistical Database
Technology effort		Scientific and technical journal articles	World Development Indicators
		Resident patents, count	World Development Indicators, WIPO Intellectual Property Database

Note: As defined in the UNCTAD Statistical database, i) human capital captures the education, skills and health conditions possessed by the population, and the overall research and development integration in the texture of society through the number of researchers and expenditure on research activities; ii) transport measures the capability of a system to take people or goods from one place to another. It is defined as the capillarity of roads and railways networks, and air connectivity; iii) energy measures the availability, sustainability, and efficiency of power sources; iv) information and communication technology (ICT) measures the accessibility and integration of communication systems within the population. It includes fixed-line and mobile phones users, internet accessibility and server security. Institution measures political stability and efficiency through regulatory quality, effectiveness, success in fighting criminality, corruption and terrorism, and the safeguarding of citizens' freedom of expression and association. For capital good import, we use the UN Broad Economic Categories to map each country's imports on the six-digit HSC. We consider the six-digit HSC products with an associated BEC code of 41 and 521 as capital goods. In the PCA, we use predicted values of patent application from a reduced-form equation that controls for country-specific and time-varying characteristics.

Figure 2 shows the average technological capability in Africa over time. The figure shows that this capability has almost doubled, increasing from 25 to 41. To a large extent, this reflects the increasing role of internet penetration and the rapid diffusion of digital technologies across African countries. Figure 3 shows the average of the composite technological capability index across space. The figure shows strong variation in the levels of technological capability among countries in Africa. For instance, South Africa has the highest composite technological capability score of 90. This is followed by Egypt, with a composite technological capability score of 81, and Tunisia, with a score of 76. Niger, on the other hand, has the lowest average technology capability score, of eight. This is followed by the Central Africa Republic and Chad, each with an average technological capability score of 11.

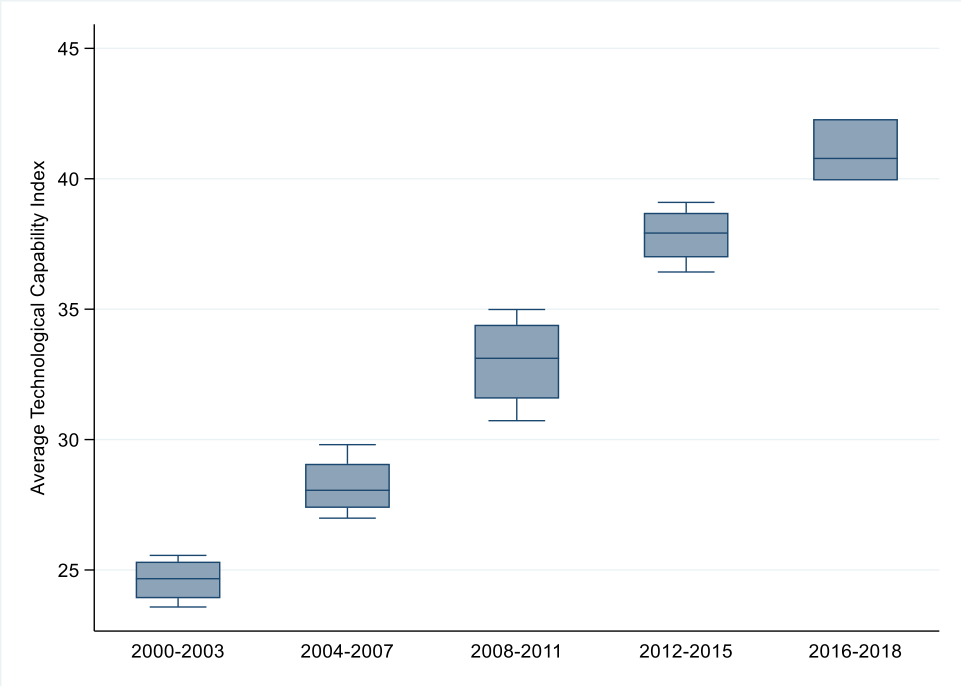

Figure 2: *Average technological capability in Africa over time*
Source: Authors' illustration based on the PCA analysis. The technological capability index is normalised, ranging from 0 to 100, with higher values indicating higher levels of capability.

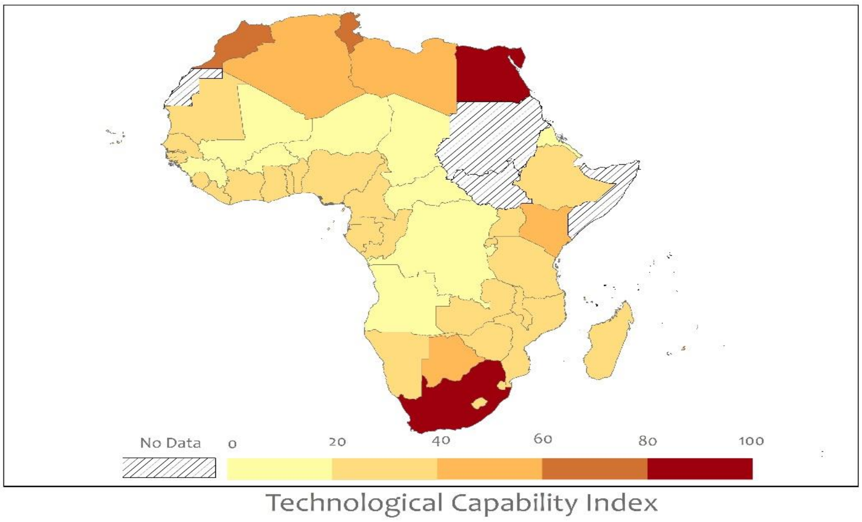

Figure 3: *Technological capability across space.*
Source: Authors' illustration based on data from the PCA analysis. The technological capability index is normalised, ranging from 0 to 100, with higher values indicating higher levels of capability.

To provide further perspective on technological capability heterogeneity within the region, we mapped the countries into four quartiles based on their technological capability (see Table 2). We associate the first quartile with regional technological capability laggards; the second quartile are regional technological capability upcomers; the third quartile are regional technological capability dynamos; and the fourth quartile comprise regional technological capability leaders. Our mapping results in 13 countries being regional laggards, 12 countries being regional upcomers, 13 being dynamos, and 12 being regional leaders. Sao Tomé and Príncipe, Namibia, Algeria, Tunisia, Cape Verde, Libya, South Africa, Morocco, Egypt, Botswana, Kenya and Mauritius are the regional technological capability leaders, while the rest of the countries are either technological capability dynamos, upcomers or laggards. At the same time, we observe a few surprises (marked in red), with a country like Nigeria ending up as an upcomer, while Liberia, Sierra Leone and Djibouti are dynamos. We highlight these as areas that warrant further investigation.

Table 2. *Regional group: Technological capability index*

Regional laggards (1st quartile)	Regional upcomers (2nd quartile)	Regional dynamos (3rd quartile)	Regional leaders (4th quartile)
Burkina Faso	Senegal	Lesotho	Sao Tomé and Príncipe
D.R. Congo	Congo	Liberia	Namibia
Chad	Mauritania	Comoros	Algeria
Eritrea	Madagascar	Ghana	Tunisia
Mozambique	Benin	Togo	Cape Verde
Burundi	Cameroon	Gabon	Libya
Angola	Zimbabwe	Sierra Leone	South Africa
Ethiopia	Guinea-Bissau	Swaziland	Morocco
Mali	Nigeria	Tanzania	Egypt
Guinea	Zambia	Djibouti	Botswana
Niger	Equatorial Guinea	Uganda	Kenya
Central African Republic	Gambia	Rwanda	Mauritius
Côte d'Ivoire		Malawi	

Source: Authors; illustration based on data from the PCA analysis

Technological and industrialisation interdependence

Considering the spatial variation in technological capability and potential spillover effects, we employed a spatial econometrics approach to empirically examine the direct and indirect effects of technological capability and industrialisation in Africa. The direct effects measure how a country's industrialisation trajectory is determined by its technological capability, while the indirect effects are the effects arising from the technological capabilities of its spatial partners – that is, other African countries. Our spatial model also includes a spatially lagged indicator of industrialisation, further enabling us to determine whether industrialisation in Africa is spatially interdependent.

Appropriate identification of the relationships we explored depended on choosing the right weighting matrix, as different matrices capture different channels of spillovers. We used bilateral trade to compute the weighting matrix. This choice was motivated by anecdotal and empirical evidence indicating that international trade plays a significant role in the spread of both industrialisation and technology (Falvey et al. 2004; Jaworski and Keay 2020; Puga and Venables 1998).

Nevertheless, we tested the robustness of our results by using either distance or contiguity as a weighting matrix. We explored variations in the share of manufacturing value added in GDP as a measure of industrialisation, but also tested the sensitivity of our results to indicators of manufacturing competitiveness.

The econometrics results provide limited evidence of industrialisation interdependence. Particularly, although we find that industrialisation in one African country can positively drive industrialisation in other African countries, the result is largely statistically insignificant. The result may be explained by the existing poor manufacturing base in the region. However, the results on the direct and indirect effects of technological capability on industrialisation show strong evidence of a positive association. This implies that improvements in the technological capability of a given African country are positively associated with industrialisation not only in that country, but also in the rest of African countries. Akin to this, we find that i) the magnitude of the indirect effect is greater than that of the direct effect, and ii) intra-regional trade is largely the causal pathway through which the technological capability interdependence is propagated.

Concluding reflections

Our findings have important policy implications. First, the evidence for the heterogeneity of technological capability in Africa is suggestive of a unique window of opportunity for learning, given the advantages of relational proximity among African countries. Second, our result on technological interdependence calls for regional cooperation toward building technological capability on the continent, while underscoring the need to intensify intra-regional trade and build regional value chains. Cooperation in the building of digital and physical infrastructure is one area that deserves policy attention. More generally, removing trade barriers to encourage intra-African trade can be an important conduit for building capabilities and for industrial development. The African Continental Free Trade Area (AfCFTA) can be an important policy lever for achieving these outcomes.

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