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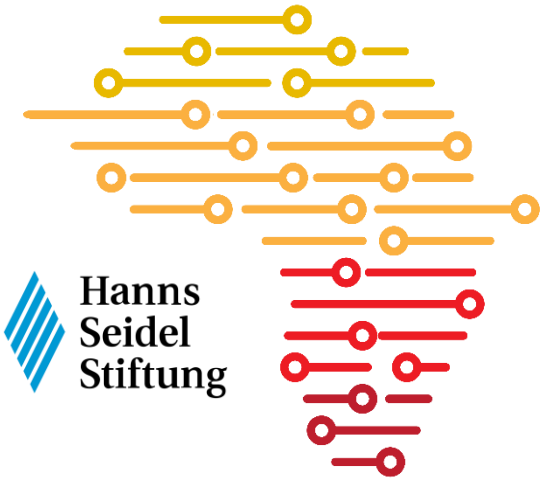

Endogenous innovation and digital inclusion: A Global African perspective

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"The central argument of the book is that issues of science and technology are so crucial to survival that they should be placed on the agenda of those items necessary for maintaining and enhancing national sovereignty." [1]

Calestous Juma and Jackton B. Ojwang *(Innovation and Sovereignty, 1989)*

"Now, in the age of big data, many of us continue to be monitored and measured, but without the audible rumble of helicopters to which we can point. This doesn't mean we no longer feel what it's like to be a problem. We do. This book is my attempt to shine light in the other direction, to decode this subtle but no less hostile form of systemic bias, the New Jim Code."[2]

Ruha Benjamin *(Race after Technology, 2019)*

"I am passionate about the incredible potential Africa has to become a truly connected continent that exports digital goods and services to the rest of the world. I am delighted to have the opportunity to meaningfully impact this growth and help unlock the continent's full digital potential." [3]

Kunle Awosika *(Managing Director, Microsoft Africa, 2022)*

[1] Juma C. and Ojwang J.B. 1989. Innovation and Sovereignty. In Juma C. (ed.). *Innovation and Sovereignty: The Patent Debate in African Development:* 7–27. African Centre for Technology Studies.
[2] Benjamin R. 2019. *Race After Technology: Abolitionist Tools for the New Jim Code.* Polity Press.
[3] Microsoft News Center. 2022. 6 September. *Kunle Awosika appointed to lead Microsoft's Africa Transformation Office.* https://news.microsoft.com/en-xm/2022/09/06/kunle-awosika-appointed-to-lead-microsofts-africa-transformation-office/

Endogenous innovation and digital inclusion: A Global African perspective

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Abstract

This paper systematically reflects on the myriad ways in which Africans, understood as a global people who include their Diaspora, can more effectively draw on their own technological capabilities in order to achieve more inclusive and equitable digital outcomes. We begin with the observation that while ongoing scholarly and policy discourses on the global digital revolution optimistically highlight its opportunities for African societies, the imperative of the domestic contribution to these – endogenous innovation – is often buried among numerous other considerations. As such, our study delineates the diverse, though mutually reinforcing, ways in which endogenous technological innovation, ranging from research and development (R&D) to the novel deployment of existing technologies, is effectively employed by intentional actors in state, private sector and grassroots organisations. Digital governance in this perspective is then informed by constant attention to the interplay between these two dimensions (governance and technological innovation) with the ultimate aim of achieving universal and equitable digital access, particularly in less privileged Global African societies, and within a relatively short time horizon. Lastly, informed by historical path dependence, that is, philosophical, technical and experiential examples from the past, we develop a conceptual framework which we call endogenous digital innovation. This framework more explicitly highlights some of the critical pathways that could lead to desirable socio-technical futures in the African world.

Introduction

Notwithstanding the rapid increase in digital goods and services in Africa, there remain notable disparities with respect to Internet access and digital literacy. This digital divide exists both within countries and across countries in Africa in a period of rapid cyber-physical technological change that some analysts refer to as the Fourth Industrial Revolution (4IR). A comprehensive analysis of the myriad opportunities presented by 4IR technologies for Africa's structural transformation has been eloquently articulated in a recent book by Signé (2023). Landry Signé considers the 4IR normatively: it is as much about technical productivity as it is about significant alterations in human life – thereby subscribing to the influential Science and Technology Studies (STS) scholar, Sheila Jasanoff's notion of 'sociotechnical imaginaries' (Signé, 2023). Yet, we are reminded by the esteemed African American theoretical physicist, Shirley Ann Jackson, that up to half of the economic growth in the United States (US) in the latter half of the 20th Century could be attributed to scientific and technological innovation, and that this enterprise could similarly contribute to the alleviation of human suffering around the world (Jackson, 2005). As such, we likewise seek to underscore the dimension of technological innovation from the vantage point of African agency, in the ongoing discourse on governance in the digital era.

While the widespread assumption appears to be that digital technologies are primarily developed in the Global North and should be widely diffused in Africa, Kaplinsky and Kraemer-Mbula (2022) argue that the dominant directionality of technical change is rapidly giving way to better quality 'appropriate technologies', mainly coming from Asia. Thus, rather than being agnostic or indifferent to the sources of various digital technologies in Africa, we seek to unpack the varieties of digital technical change in an effort to highlight related opportunities for closing the productivity gap with other parts of the world. Differently stated, we pay specific attention to the technological window of opportunity for industrial leadership (alongside market and institutional windows) (Lee and Malerba, 2017), but with an inclusive rather than a predominantly economic perspective on the notion of 'catching up'. In particular, we lean on the concepts of endogenous (or internally driven) innovation, as well as 'inclusive catch-up' which Soumonni and Muchie (2023: 396–397) define as 'closing the

gap in desired human development outcomes, relative to an identified reference society, a specified target, or a given date and at a faster rate than had previously been achieved'.

In sum, we depart from the indiscriminate and minimalist nomenclature of technological 'adoption', and replace it with the logics of upgrading, originality and appropriability (deriving benefits from innovative activity). In so doing, we seek to outline a deeper and more systematic appreciation of digital innovation (novelty and usefulness) needed in governance initiatives. We therefore propose the concept of 'endogenous digital innovation' to address this theoretical deficit and reflect on the governance dimension through the prism of 'Global Africa', now formally adopted by the United Nations Scientific, Educational and Cultural Organization (UNESCO) to capture both contemporary and historical Diasporic and transcontinental African communities (UNESCO, 2021).

The paper proceeds as follows: First, we provide an overview of the digital divide in Global Africa. We then reflect critically on endogenous innovation in the digital age, as a lens through which the notions of digital innovation and inclusion can be better understood. In that context, we more narrowly draw attention to big data, defined as 'large, diverse, complex, longitudinal, and/or distributed data sets generated from instruments, sensors, Internet transactions, e-mail, video, click streams, and/or all other digital sources available today and in the future' (NSF-NIH Interagency Initiative, 2012: 2). We give due consideration to the related importance of data science, defined as the 'ecosystem dedicated to the systematic collection, management , analysis , visualization, explanation and preservation of both structured and unstructured data' (Marshall and Geier, 2019). We also pay attention to artificial intelligence (AI), which can be understood as a machine-based system that is capable of identifying patterns in large amounts of data and producing predictions, such that AI governance actors can improve public sector decision making, while mitigating its risks (Galindo et al., 2021). We view these as the key representative 4IR digital technologies (and techniques) in our study with respect to their implications for socio-economic inequality. We then elaborate on a framework for endogenous digital innovation that makes explicit the interplay among categories of technological innovation on the one hand, and governance actor categories on the other. We demonstrate the value of this framework with empirical evidence from mini-case studies around the African world. Lastly, we conclude with

recommendations for an innovative Global African society that cuts across governmental, private sector and civil society actors who are animated by a common emancipatory ideal.

Characterising the digital divide in Global Africa

It is important to characterise the notable digital divide in Africa, in spite of the rapid increase in the adoption of digital goods and services. Approximately 43% of the African population is online, compared to the global average of 64.2% (combined, non-African nations are at 68.6%) (Internetworldstats, 2022). If we take a cross-section of countries in various African regions, Kenya, Algeria and, surprisingly, Libya, are the African leaders at 85.2%, 83.8%, and 94.8% respectively of their populations online. South Africa's population that is online is at 57.5% (ranked behind its BRICS peers, China, India, Brazil and Russia), while the percentage of Nigeria's population with Internet access is 73.0%. Seventeen countries have access rates below 20% and three countries – Eritrea, South Sudan and Western Sahara – are below 10% (Internetworldstats, 2022). In North America, the United States and Canada have access rates of 93.4% and 97% respectively, while South American countries with large African descended communities like Brazil and Colombia, record 82.8% and 83.9% respectively (Internetworldstats, 2022). Although the average access rate to the Internet in the Caribbean is slightly lower than the world's average at 67.1% (the world's average is 69%), there is also a wide internal disparity. Small island states such as Bermuda and the Cayman Islands have over 100%, but larger islands such as Jamaica record 68%, while Haiti is at 35% (Internetworldstats, 2022).

Furthermore, the digital divide with the broader African Diaspora is particularly stark, reflecting that many people of African descent remain digitally and socio-economically marginalised. Approximately 13.6% of the US population self-identifies as Black or African American (US Census, 2020). However, despite overall increases in the percentage of adults who report Internet usage (93% in 2021), 23% of US residents report a lack of home broadband use (Atske and Perrin, 2021). Disaggregating by sociodemographic characteristics, we find gaps in relation to age, race, income, level of education and geography. For example, ownership of a traditional computer or access to high-speed Internet at home is less likely for US Black adults (71%) than US White adults (80%) (Atske and Perrin, 2021). In the Black rural

south, 38% of African Americans report that they lack home Internet access, compared to 23% of White Americans (Harrison, 2021).

For the 133 million African-descended people living in Latin America (approximately 25% of the entire population), they are two and a half times more likely to experience chronic poverty than other groups (Srinivasan et al., 2022). In Latin America and the Caribbean (LAC) countries, 67% of households have fixed Internet access (Srinivasan et al., 2022). However, this access varies significantly by within-country region and between rural and urban regions: just 42% of rural households have Internet access in LAC countries compared to 74% of urban households (Srinivasan et al., 2022). The general lack of disaggregated published data by race/ethnicity on Afro-descended groups remains a challenge. However, some LAC countries have made this data readily available, particularly as it relates to Internet access and usage. For example, in Costa Rica, 66% of people of African descent (ages 15 to 17) in urban areas had used the Internet in the past three months, compared to 40.7% in rural areas (Srinivasan et al., 2022). This is in contrast to 73.9% of non-Afro-descended people (excluding Indigenous and Asian people) in urban areas and 49.8% in rural areas (ECLAC/OHCHR, 2020).

Furthermore, 2018 household surveys across five LAC countries (Brazil, Colombia, Ecuador, Peru and Uruguay) reveal significant gaps between Afro-descended and non-Afro-descended people. More than half of the Uruguayan Afro-descended population (52%) has Internet access at home, but this rate is much lower than that of the non-Afro-descended Uruguayan population (70%). In Brazil, Colombia and Ecuador, nearly 30% of the Afro-descended population have Internet access, and this rate drops to less than 25% in Peru (ECLAC, 2020). The Internet access gap between Afro-descended and non-Afro-descended people ranges from 11.5 percentage points in Ecuador to 21.0 percentage points in Brazil (ECLAC, 2020). This persistent gap in digital infrastructure and access for African-descended people informs our choice of ‘Global Africa’ as a concept that is officially and operationally recognised by UNESCO (UNESCO, 2021). Table 1 below provides a snapshot of the rates of Internet access in selected countries in the African world, or Global Africa. The reader should note, however, that the actual number of Internet users (particularly in the Global South) typically exceeds the number of subscribers who may share their Internet connections with other users (InternetWorldStats, 2023). Furthermore, the Internet penetration rate implies the

percentage of a total population whose members have access to the Internet and who have sufficient knowledge to operate web-related technologies (InternetWorldStats, 2023).

Table 1: Cross-section of Internet access rates in Global Africa

Regions	**Countries**	**Internet Access Rates**
Africa	Ghana	45.9%
	South Africa	57.5%
	Democratic Republic of Congo	17.4%
	Kenya	85.2%
Caribbean	Jamaica	68.0%
	Trinidad and Tobago	81.2%
	Barbados	79.9%
	Haiti	35.0%
South America	Brazil	82.8% - ~61% for Afro-descendants
	Uruguay	93.2% - ~52% home Internet for Afro-descendants (relative to 70% for others)
	Ecuador	86.4% - ~75% for Afro-descendants
	Colombia	83.2% - ~30% for Afro-descendants
North America	USA	89.8% - ~70% home Internet for Afro-descendants
	Bermuda	96.9%

Sources: InternetWorldStats, 2023; ECLAC/OHCHR, 2020

Rethinking endogenous innovation in the digital age

Digital technologies and digital inclusion

Digital inclusion seeks to counter the concept of the digital divide, which examines how demographic and socio-economic conditions, including income, education, age and gender, affect how the Internet is used and accessed (Ragnedda and Muschert, 2013). The increasing performance of digital technologies offers critical opportunities, but represents an insufficient basis to promote inclusion. Since the invention of the transistor and its widespread diffusion in the 1950s, digital technologies (based on processing binary digits rather than analog

signals) have increasingly become more powerful, while simultaneously becoming cheaper and more accessible. This was accomplished via two well-known and mutually reinforcing industry-driven conjectures, known as Moore's Law (the processing power of microprocessors effectively doubles every 18 months) and Metcalfe's Law (the value of a network – Internet, cellular or otherwise – will increase with the square of the number of its participants) (Metcalfe, 2013).

Indeed, the Pulitzer Prize winning 1981 book *The Soul of a New Machine* by Kidder (2011), describes in fascinating detail the highly profitable race to develop affordable personal computers in the US in the 1960s and 1970s. This period can be said to correspond to the first phase of the digital or information age, often identified as the Third Industrial Revolution (3IR). It may be contrasted with the emerging, but contested, Fourth Industrial Revolution (4IR), which Lee and Lee (2021) demonstrate is more an evolution or second phase of the 3IR, rather than representing a radically different technological regime. Jongho Lee and Keun Lee nevertheless posit that significant change in societal impact (with the possible exception of artificial intelligence) is yet to be determined, thereby introducing some moderation into the debate on the societal impact of the 4IR relative to the 3IR (Lee and Lee, 2021). It is worth noting here that an early reflection on the intellectual property regime for computers in Kenya by Okech-Owiti (1989) underscored the emergence of artificial intelligence research to mimic the brain's neurological functioning. Moreover, the context in 1989, during which Okech-Owiti argued that the monopoly over computer hardware, software and accompanying accessories by international firms would limit the purchasing power of consumers, remains of enduring relevance for endogenous innovation in Global Africa. This monopoly position is certainly reflected in both the 3IR and the 4IR, in terms of the five dominant countries, which are the US, South Korea, China, Germany and Taiwan (with China replacing Japan in the 4IR) (Lee et al., 2021). And the longstanding corollary insight is that any increase in market shares by latecomers cannot be sustained without an increase in technological capabilities, due to the difficulty of gaining preferential licensing agreements over an extended period of time (Lee and Lim, 2001).

Given the underlying premises above, the fundamental expansion of the digital infrastructure in Global Africa therefore requires its scientists, engineers, entrepreneurs, innovators and

government agencies to engage the full spectrum of e-commerce and e-governance initiatives to realise success in the global innovation marketplace. In the computing domain, a path-breaking approach based on multiprocessors was advanced in the mid-1990s by Kunle Olukotun, a professor of electrical engineering and computer science of Nigerian descent at Stanford University. His approach enabled the performance of computer chips to transcend the theoretical limit predicted by Moore's law (Olukotun and Hammond, 2005; Olukotun et al., 1996). This highly impactful technology is driven by novel computing principles, techniques and algorithms that enable the parallel processing of independent tasks, in a manner that is both orders of magnitude faster and significantly more energy efficient (Aly et al., 2015). Kunle Olukotun subsequently founded a company in 2000, named Afara Websystems, to commercialise this multicore processor technology (called Niagara) – afárá means 'bridge' in the Yorùbá language of West Africa. In 2014, he founded a fintech startup company called Migo (informed by a Stanford research project) that uses advanced machine learning tools and graph algorithms (unique data structures) to analyse smartphone data, in an effort to offer affordable financial services (credit) to scores of millions of unbanked adults in Nigeria and other emerging economies such as Brazil (Kazeem, 2019).

Concurrent with this expansion of digital ecosystems, however, are persistent inequalities in Internet access emanating from historically rooted systems of social stratification within and between countries. As such, to achieve digitally inclusive societies, a deeper and more systematic appreciation of digital innovation should be placed at the centre of governance initiatives. Governments and other public sector organisations are therefore increasingly seeking ways to leverage information, communication and technology (ICT) tools and big data (i.e., data that is high in volume and/or of high velocity and veracity, and that requires new technologies and techniques to collect, store and analyse), in order to improve the efficiency, flexibility, effectiveness and personalisation of public services (Mills et al., 2012; Munné, 2016).

What is digital innovation?

Clarifying the concept of digital innovation is an ongoing topic of many studies, reviews and revisions (Ancillai et al., 2023; Hund et al., 2021). However, while a working concept of

innovation is sufficiently well understood from a diversity of perspectives in innovation studies (economics of innovation, innovation management, innovation policy), it is the qualifier 'digital' which needs to be clarified and brought into a critical discourse with existing and emerging approaches to the study of innovation. For our purposes, we understand innovation as a collaborative process that starts from the conceptualisation of a problem to capturing value in a manner that involves various intentional actors working together to combine novel technological and organisational solutions in order to achieve their goals. Digital innovation therefore must lean, in part, on digital technologies that typically function by converting the analog information encountered in everyday life into the numerical or binary logic of computers through a process of digitisation.

The new numerical format of this previously analog information is stored in binary digits (bits), which are stored in structures known as bit arrays or bit strings. These bit strings can then be identified as 'digital objects' that, when used or combined to fulfil a socially recognised function, can be described as 'digital technologies' (Hund et al., 2021). The conversion of analog information to binary digits, and the intersection among new bit-based technologies (such as blockchain, cloud computing or the Internet of Things) on the one hand, and novel or adapted forms of social organisation (such as business models or policies) that enable societal value addition, on the other hand, constitute what we refer to as 'digital innovation'. While it is important to underscore that technological innovation and organisational innovation mutually shape one another, it should also be noted that digital innovation is not merely a narrow combination of both, but typically requires dynamic capabilities on the business side to adapt to rapidly changing technologies (Ancillai et al., 2023).

Furthermore, it is now well established in the academic literature that innovation can be better understood in a broad, systemic perspective (that is, beyond interactions among a limited set of actors) (Lundvall et al., 2009). This approach, with its emphasis on the policy and firm-driven initiatives for competence building as well as domestic research and development (R&D) efforts aimed at increasing a country's position with respect to the global value chain, has been reflected upon in the context of India's ICT sector by Joseph (2009). In the context of the current digital revolution, national innovation systems are increasingly

being understood as being engaged in a highly contested and politically conflictual innovation race (Lee, 2021; Rikap and Lundvall, 2021).

However, given the vast, diverse and interconnected nature of the digital sector, this paper adopts a simplified classification scheme that enables us to demonstrate our insights. We consider the analysis of lasting inputs into production in the earlier phase of the current digital revolution by two leading American economists, Richard Nelson and Paul Romer. Nelson and Romer (1996), who work in the evolutionary and neoclassical economics traditions, respectively, referred to three main inputs: hardware (capital goods and natural resources), software (information stored outside the brain) and wetware (human capital, skills and tacit knowledge). However, given the significant role of services in achieving digital disruption and transformation, from cloud-based retail services to social networking, entertainment and even educational services (Demirkan et al., 2016), we replace the 'wetware' category with services in order to underscore the necessary interplay among hardware, software and contextual know-how in meeting socio-economic needs. This modification is further justified by the notion of knowledge intensive business services (KIBS) which in the case of the digital revolution are technology-based (rather than professional), and combine high levels of human capital, knowledge and intangible resources to boost the performance of local industries (Vaillant et al., 2021).

Endogenous digital innovation

We seek to specify the parameters of digital innovation that interest us by rooting this in the cross-cutting concept of endogenous innovation. In the neoclassical economics tradition, endogenous growth came to prominence primarily through the work of the economist, Paul Romer. He identified the intentional investment by domestic firms in their own R&D as the distinguishing determinant of long-term growth in contrast to the previously dominant exogenous growth theory that did not account for this organisational level variable. Romer (1994) then summarised his new theory in the form of the following equation:

$Y = A(R)F(R_j,K_j,L_j) + \varepsilon$ (1) (Romer, 1994)

Y is GDP output in a given year, A(R) is the public investment in R&D, K_j and L_j are the two classical factors of production, capital and labour, and R_j is the investment in R&D by a firm j.

However, if we broaden the idea of investment in innovation beyond R&D, Grossman and Helpman (1991) argue that the manufacturing performance of domestic firms in industrialising economies is more decisive. By analogy then, an investment in the capacity to produce digital goods and services, beyond generating economically useful new knowledge, would satisfy the need to 'endogenise' digital innovation. A relevant study on the hard disk drive industry demonstrated that, while France and Germany primarily invested in basic research on giant magneto-resistance (GMR), the US and Japan reaped the dominant returns because the latter countries' firms had a greater absorptive capacity (involving firm-level R&D) to drive commercialisation and ultimately boost their local economies (Dedrick and Kraemer, 2015). However, a key additional resource for digital innovation, beyond capital and labour, is big data. As such, in an important keynote address presented at the Schumpeter Conference in 2022, Xiaobo Wu (2022) proposed modifying the endogenous growth equation along the lines of the equation below:

$Y = F(A,\mathbf{D},K,L) + \varepsilon$ (2); where D represents big data and related information platforms(Wu, 2022). For consistency with Romer's equation, we reformulate the equation above below as:

$Y = A(R)F(R_j,K_j,L_j\ \mathbf{D_j}) + \varepsilon$ (3); where D_j represents big data information platforms invested in by a firm, j.

The error term, sometimes called the Solow residual, represents more than 80% of the unexplained variation in productivity growth. This 'black box' can be investigated through other theoretical approaches, including the national innovation systems framework (Lee, 2021).

To address this theoretical deficit, we further disaggregate 'endogenous digital innovation' into technological and governance dimensions. The technological dimension allows for a significant improvement in imported technologies, the development of novel ones, or both. In the governance domain, we underscore a diverse range of productive organisations (non-governmental, governmental and grassroots organisations). Lastly, informed by a third dimension – historical path dependence – we hypothesise that the co-evolution of these dimensions should lead to more inclusive digital access across gender, class, linguistic and cultural divides.

Big data as a new 'resource curse'?

Big data has been termed the 'new oil', implying the need for larger, faster and more varied data, but while emerging digital platforms make it easier for African entrepreneurs to participate in the digital economy, these entrepreneurs will need to find competitive niches in the face of aggressive investments in data acquisition by global software giants (Signé, 2023). Indeed, a study on Amazon's rapid emergence as the leading R&D company in 2017 demonstrates the emphasis of its investment in big data collection systems and architectures on the power of user participation (Tou et al., 2019). Moreover, various commentators also argue that there is a complex social system of digital and human actors who often experience unevenly distributed costs and benefits along historically racialised, gendered and various other demographic and socio-economic lines. Natural resource-abundant nations, particularly those in the South (for example, LAC and African countries), are familiar with this phenomenon of unequal distribution.

The paradoxical relationship between the abundance of oil and other natural resources (such as precious metals and minerals) in many African and LAC countries and the persistently low per capita income of their populations is referred to as the 'natural resource curse' (Frankel, 2010). This 'curse' has only become more apparent due to the decades-long increases in the speed, storage capacity and affordability of smaller digital technologies (due to Moore's Law). However, the irony of the Western-dominated technological and commercial industry abundance in the context of Silicon Valley is that this White and male-dominated industry has perfected the art of exclusion of African-descended and Latino workers (Noble and Roberts, 2019) while disproportionately depending on consistent access to semiconductor raw material from the African continent. The abundance of these raw materials can be seen throughout the African content – cobalt in the Democratic Republic of the Congo; chromium, iridium and manganese in South Africa; and gold in Ghana. Nevertheless, semiconductors have not been processed on the African continent until very recently, where both bulk and nanotechnology-based chips are being manufactured by Semiconductor Technologies Limited at the Dedan Kimathi University of Technology's Science and Technology Park in Kenya (Wanjala, 2021). The rise in access to, and use of the Internet and big data technologies (mobile devices) across Africa and the African Diaspora via platforms that are owned and

operated by globally dominant actors, without commensurately shared benefits, is rightfully a major concern for scholars and practitioners seeking to protect and empower African people. The discussion on artificial intelligence in the sub-section below brings such concerns into greater relief.

Artificial intelligence and the reproduction socio-economic inequality

Advances in digital technology have historically excluded, ignored, marginalised and harmed people of African descent. Evidence from the US suggests that the digital technologies being developed reflect the dominant ideologies of the majority White male demographic of the US technology workforce (Cook et al., 2022; Cook and Kongcharoen, 2010; Monroe-White et al., 2021). For example, facial recognition software developed by IBM, Amazon and Face++ disproportionately misclassified darker-skinned females (34.7%) more than lighter-skinned males (0.8%) (Buolamwini and Gebru, 2018). When used in concert with massive law enforcement databases (those with images of over 117 million US adults) for police and government surveillance, such software can, in turn, lead to the false identification of innocent suspects (Buolamwini and Gebru, 2018).

Digital harms also emerge in search engines. Search engine algorithms return results that reinforce negative stereotypes associated with Black people. For example, Noble (2018) found that search terms such as 'Black girls' and 'Black women' have yielded pornographic and profane first-page search results in Google Search. In yet another case, investigative journalists found that US Black defendants who were subjected to the COMPAS (Correctional Offender Management Profiling for Alternative Sanctions) algorithmic tool were twice as likely to be misclassified as higher risk as similarly offending White defendants, thus reinforcing incarceration rates which directly target and help to ensure the continued marginalisation and oppression of Black people (Angwin et al., 2022).

These inequalities reinforce the systemic racist practices and policies that, for centuries, have led to the exclusion and marginalisation of Black and other marginalised groups from full participation in social and economic institutions. Efforts to mitigate these harms are also increasing among African scholars, researchers and activists from across the Diaspora, as

exemplified, for instance, in the work of Monroe-White (2021). And in Africa, Nyakundi (2022) reports that AI researchers are creating communities and organising themselves to warn the general public about AI surveillance and discrimination across the continent.

Conceptual framework: Endogenous digital innovation

The conceptual framework in this study is informed by the need to better systematise digital technological innovation activities carried out by domestic firms and organisations, such that governance activities serve to promote greater endogenous innovation, rather than being aloof to the sources of technical change. Thus, while Signé (2023) correctly concludes his book with an observation that Africa's deficit in infrastructure and R&D investment should not preclude its people from embracing new technologies, we argue further that a more systematic innovation-based analysis can signal the way in which Africans can help shape these technologies themselves in conjunction with their own social imaginaries. For instance, the R&D investment by national governments and domestic organisations, even if modest, should be much more intentionally directed to opportunities for value capture across both emerging and mature domains, which would result in original innovation. A significant portion of such R&D-based investment in emerging technologies should also be judiciously and explicitly targeted to identified socially inclusive outcomes in a manner that meaningfully improves human well-being, as has previously been argued by Soumonni (2016). Scientifically novel digital goods and services that have already been developed elsewhere can then be independently imitated (with all due attention to intellectual property considerations) and adapted to the niche local demand through what is known as secondary innovation (Wu and Zhang, 2010).

Some examples in the case of digital hardware would be the development of digital televisions by South Korean firms, China's Huawei's telecommunications equipment and ZTE's imitation of foreign telephone switching systems for application in rural areas (Wu and Zhang, 2010). Secondary innovation capabilities can also relate to advanced software design. These include the development of digital platforms to drive even greater value co-creation from goods and services, transportation, housing, e-government and labour markets (Fu et al., 2021). Such platforms are being used to boost agricultural productivity in various places, such

as *Hello Tractor* in Nigeria (developed by IBM) to provide farmers with on-demand tractor access, and *iCow* (involving Safaricom) for exploiting big data in East Africa (Kaplinsky and Kraemer-Mbula, 2022). More domestically driven platforms (based on endogenous innovation) feature prominently in major mobile payment platforms such as M-PESA in East Africa (Mworia, 2016) and Paystack, based in Nigeria, among more than 300 unique platforms in Africa (Signé, 2023). The exploitation of existing technologies of a superior performance than what can be developed locally, combined with advanced business models, is consistent with knowledge-intensive business services (KIBS) and can be referred to as a tertiary innovation (Corrocher et al., 2009).

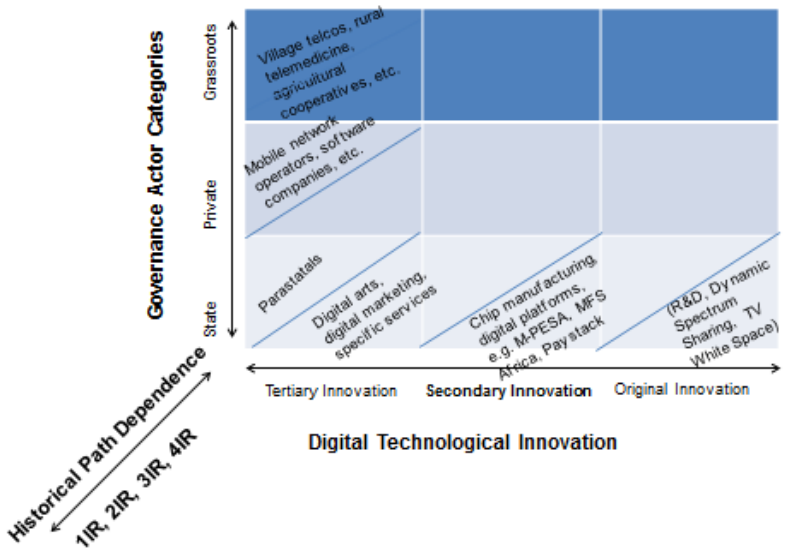
The tertiary innovation mode characterises much of what are deemed to be opportunities for Africa to benefit from the 4IR. But, if African societies are to close the technological and productivity gap between themselves and frontrunners in the future, they would need to be more deliberate about increasing their share of secondary and original innovation, at least in those domains that are of urgent relevance to them. The intentionality required to do so cannot be taken for granted, however. Societal actors who have taken the time to become knowledgeable, invest in and deploy their innovative efforts to tackle problems of socio-economic relevance can then be identified based on their track record. The three broad actor categories in an 'innovative society', following prior work by Soumonni and Muchie (2023), have been identified as the state, the private sector and grassroots organisations. The specific actors within those categories who have a track record of inclusive innovation can then be identified through a third dimension which we call historical path dependence. Three principles developed by Soumonni and Muchie (2023) for employing historical experiences to inform innovation exchanges in the Global South are informed by a Global African perspective. To be used singly or in combination, they are as follows:

i. Historical accomplishments could serve to inspire present-day efforts.
ii. Historical experiences could provide clues to insightful technical knowledge.
iii. These experiences and accomplishments may help to recover certain societal arrangements, norms, practices or linguistic modes of communication that may still be relevant.

Figure 1 below shows some combinations of digital technological innovation and innovation actors in a 3x3 matrix. In terms of digital technological innovation, the R&D-driven solutions

for rural broadband access based on dynamic spectrum sharing, when implemented, reflects original innovation. The manufacturing of chips, such as by Semiconductor Technologies Limited in Kenya, and other digital equipment (beginning with assembly), reflects secondary innovation with respect to hardware. Secondary innovation also characterises the independent development of advanced digital platforms that serve to diffuse numerous services. The mobile money platform exemplified by M-PESA, as well as other digital platforms developed by MFS Africa and Paystack, are analogous to capital goods or production technologies, and can likewise be classified under secondary innovation. Lastly, digital goods and especially services that have some technological content but are primarily driven by their diffusion models, such as digital arts, digital marketing and specific payment apps or related services, represent tertiary innovation. The various societal actors, who could then intentionally deploy their capabilities to exploit endogenous technological innovation in order to address grand missions, can be categorised as state, private sector and grassroots (including civil society and social enterprise) actors.

Figure 1: Endogenous digital innovation in Global Africa



The third dimension in Figure 1 above provides the analyst with a historically informed judgement about which actors have what capabilities, and which are willing to direct those towards inclusive catch-up, that is, achieving desired developmental outcomes at a faster

pace than is currently obtained. In this manner, the agency of actors is underscored and their propensity for interacting with other actors can be assessed. Furthermore, the contribution of Global Africans to epochal technological and industrial revolutions, as well as the diverse impacts of these changes on their societies, can provide some guidance on how best to effect a more equitable socio-technical transition, aided by cultural imaginaries, in the digital age. Thus, the recognition of pioneer innovators in wireless telecommunications networks, such as Jesse E. Russell (2G networks) and Mo Ibrahim (renowned expert in mobile communications and founder of Celtel), is important when recognising that Global Africans are fundamental contributors to contemporary technological advances. Likewise, Shirley Ann Jackson's theoretical research breakthroughs that informed the development of fibre-optic cables (among other developments) and Fisseha Mekuria's more recent breakthroughs in dynamic spectrum sharing for affordable, rural broadband access, are signposts that re-centre our attention on the importance of endogenous technological innovation in achieving broader governance outcomes. The overriding objective here is to reverse the socio-economic inequalities that were co-constitutive of the First Industrial Revolution and which have persisted in structural terms through subsequent industrial revolutions.

Exemplary case studies in Global Africa

Finally, we briefly highlight some exemplary innovators and governance actors from Global Africa who have contributed to digital inclusion, including through African languages and for the hearing impaired.

Case #1: Dynamic spectrum sharing for low-cost rural Internet

The imperative of universal Internet access, which foregrounds participation in the digital age, is an outstanding task in Global Africa, as demonstrated. Yet, it also represents an innovation challenge which is being addressed by various actors. We highlight R&D-driven activities in network innovation, which could offer affordable and universal broadband Internet access, particularly in Africa, based on spectrum sharing for 5G networks. This is based on the observation that radio frequency spectrum resources are statically and ineffectively allocated, and should be replaced with smart sharing systems that are augmented by artificial

intelligence techniques (Mekuria and Mfupe, 2019). Based on this approach, television white spaces (TVWS) broadband network technology has been deployed at 10 underserved schools in the Western Cape province of South Africa through the use of unlicensed (free of charge) 5G spectrum networks (Mekuria and Mfupe, 2019). This research effort based at South Africa's Centre for Scientific and Industrial Research (CSIR) has been led by Fisseha Mekuria, who holds several patents in the area of telecommunications networks, including some relating to dynamic spectrum sharing, thereby demonstrating proof of concept. When combined with appropriate business model innovation for both licensed (allocated for private use) and unlicensed (free) spectrum bands (Banda et al., 2022), universal broadband Internet access in urban and rural areas alike could become a reality within a reasonable time horizon.

Case #2: Artificial intelligence and natural language processing for linguistic and conceptual agency

The imperative of inclusive digital innovation cannot circumvent the use of African and African-derived languages, which are spoken by the overwhelming majority of the population in Global Africa. According to Prah (2008), not only is mother tongue education the missing link in African developmental endeavours, it also reflects that sharing information and knowledge in familiar languages is critical for democratic empowerment. Endogenous digital innovation may therefore exploit the myriad opportunities for the deployment of artificial intelligence and machine learning for natural language processing (NLP) to enable the translation of publications, spell checking, word prediction and so on from European languages into the widely used African national languages, and vice versa (Marivate, 2021). This has been demonstrated for Setswana (Dibitso et al., 2019) with respect to Part of Speech (POS) tagging, which is a critical step in NLP that allows lexical categories (or parts of speech) to be appropriately assigned to words in a sentence, thereby making it meaningful. More broadly, related Machine Learning and Artificial Intelligence techniques have been applied to nine Southern African languages with the objective of enabling the interaction of their speakers with intelligent machines, such that their perspectives are fully heard in the emerging digital revolution (Marivate, 2021).

Case #3: Web, Animation, Visualization and E-learning (WAVE) research lab, University of the West Indies (UWI) Mona – Jamaica

The social, cultural, philosophical and historical imaginaries among African descended communities represent aesthetic sensibilities as well as critical reflections that need to find greater expression in the digital age. Founded by Ashley Hamilton-Taylor, the Web, Animation, Visualization and E-learning (WAVE) research lab based in the computer science department at the University of the West Indies is a pioneering unit that gives its students a range of technical skills and capabilities to express their immediate Caribbean heritage and broader African (or other) civilisational backgrounds. A particularly innovative research and teaching initiative is the use of 3D computing or 3D cinematography, which has been used to capture and share some historic Ethiopian sites among people who may have never been there physically, thereby enabling them to better understand and identify with their ancient African heritage. Other activities relate to User Interface (UI) design, the development of animation and games for social upliftment, and critical perspectives on computers and society. As with other African/African-derived languages, researchers associated with the laboratory have also developed synthetic voice applications (for example, text-to-speech synthesis) based on Jamaican Creole for visually impaired and hearing impaired members of the society (Thompson and Hamilton-Taylor, 2014). All of these endogenous innovative efforts (reflecting original, secondary and tertiary capabilities) give voice to contemporary socio-technical imaginaries from a Global African perspective.

Case #4: Strengthening digital governance in Ghana

In 2001, the United Nations (UN) developed the E-Government Development Index (EGDI) used for its biennial surveys to assess efforts among its member states to enhance government electronic services. The EGDI provided a holistic view of e-government development and a solution to the limitations of prior adoption models. In addition to online services, this framework also considered the human capacity to use information communication technology (ICT) and the availability of ICT infrastructure (UNDESA, 2014). Adjei-Bamfo et al. (2019) conducted a systematic literature review of the role of e-government in the mainstreaming of sustainable public procurement in an emerging country context. They reported that digitisation efforts in Ghana are thought by analysts to be

hampered by limited infrastructure, a low level of integration of public agencies, vulnerable privacy management systems, weak security, lack of strategic plans, low awareness of e-government projects and insufficient capabilities to use e-systems. Existing digital governance adoption models (Fath-Allah et al., 2014; Layne and Lee, 2001) had been criticised for being too linear, narrow and inconclusive, as their primary focus had been limited to the prevalence and use of online services (Groznik and Trkman, 2009). As a result, researchers began emphasising the importance of addressing sociocultural and institutional circumstances to advance social equity in the emerging country context (Bertot et al., 2016; Schuppan, 2009). A multi-year engagement between a local research team and US academics led to the piloting of an effort to digitise thousands of NGO records from 2000 to 2019. This pre-pandemic initiative would have made Ghana one of the first sub-Saharan African states with a digitised e-government system for non-profit registration and records management. It remains relevant for the post-pandemic era.

Towards an emancipatory digital governance paradigm for Global Africa

Our study has sought to align the imperatives of digital inclusion and, indeed, justice with the internally directed or endogenous technological innovation capabilities of diverse actors in Global Africa. This enables a broader and deeper consideration of supra-national innovation systems that are based on common challenges, shared values, collective historical imaginations and mutually reinforcing capabilities. In combination, these can not only bridge the economic and technological gap between African communities and their own developmental aspirations (inclusive catch-up), but also do so in a manner that engenders more equitable and respectful exchanges with other often overlapping or mutually-constitutive societies. Our proposed backward and forward looking conceptual framework on endogenous digital innovation is therefore intended to inform socially conscious and identifiable agents to collectively work out equitable governance strategies for a much more societally just digital age.

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