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Seeking for the shift towards challenge-oriented innovation policies: Tracing digitalization policies over two decades in Africa

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Seeking for the shift towards challenge-oriented innovation policies: Tracing digitalization policies over two decades in Africa

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Abstract: The current innovation-policy discourse suggests a shift towards challenge-orientation and calls for a whole of government approach to tackle grand societal challenges such as climate change, inequality, and poverty. We seek for such a shift in two countries highly exposed to these challenges, South Africa and Rwanda, and in relation to digitalization policies, which hold strong transformative potential. To do so, we develop an analytical framework, which differentiates between policy goals (intended economic, social, or environmental outcomes) and policy rationales (technology-push, system building, or transformative change). Our empirical results show little resemblance to the temporality assumed in the literature, namely that policy goals and policy rationales should shift towards challenge-orientation and transformation over time. In contrast, we find that the policies relevant for the digital transformation have been challenge-driven from the beginning addressing besides economic growth also inclusivity and poverty reduction. Also, we find a potentially generalizable pattern in transformation processes, embarking from system building, then focusing on developing products, processes, and business models, and finally specializing the instruments to address specific shortcomings. The findings complement and contrast existing studies often centered on the Global North and often covering a narrower set of innovation policies.

Keywords: Innovation policy, grand challenges, digitalization, South Africa, Rwanda, transformation, system innovation, policy evolution

JEL Codes: O10, O30, O33, O38, O55

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1 Introduction

The shift towards challenge-oriented or mission-oriented transformative innovation policies implied a stronger emphasis on coordination between policy domains, and what some call a whole of government approach (Mazzucato, 2018; Schot & Steinmueller, 2018; Weber & Rohracher, 2012). This is because system transformation cannot be understood by looking at one policy domain alone, such as the traditional areas of science, technology, and innovation (STI) policies. The shift towards transformative innovation policies has also been conceptualized as the phasing in of different layers of policies from technology-push STI policies, to systemic innovation policies, to finally transformative ones. It is the latter, which, according to this discourse, emphasizes directionality beyond economic growth towards social and environmental outcomes.

This paper seeks to trace the shift towards challenge-oriented innovation policies in relation to digitalization because the coupling between digitalization[1] and sustainability represents megatrends that have continued to engage the discourses on addressing societal challenges such as poverty, inequality, and climate change. Advances in digital technologies offer potentials and pose risks for sustainable development (Zhou & Etzkowitz, 2021). For example, digital and energy infrastructures are being integrated to drive low-carbon economic development (Karlilar, Balcilar, & Emir, 2023; Mondejar et al., 2021). Digital business models create inclusive employment and entrepreneurship opportunities (McAdam, Crowley, & Harrison, 2019). However, digitalization also holds challenges for sustainable development. For example, there is the risk of increased energy consumption and emission associated with the production and use of ICTs. Digitalization also changes the nature of work, and increases wage inequalities and the risks of job loss (Frey & Osborne, 2017; Heeks, 2019). In a similar vein, artificial intelligence (AI) presents opportunities to make sense of big data, and make life and work easier, but AI systems rely on algorithms that tend to reproduce bias that locks people out of opportunities, and perpetuate existing inequalities along the lines of gender, age, class and ethnicity (Holzinger, Weippl, Tjoa, & Kieseberg, 2021; O'Sullivan, Clark, Marshall, & MacLachlan, 2021).

Despite the need to interrogate the coupling between digitalization and societal challenges, a recent systematic literature review reports that there are limited studies exploring this link (Andersen et al., 2021). There is the argument that work in this area needs to engage both conceptual and empirical aspects, as the latter is underexplored (Sareen & Haarstad, 2021). Understanding the nature and direction of these transitions is particularly important because technology, in itself, lacks the agency to deliver the desired economic and social outcomes (Geels, 2002).

Addressing the dearth of literature explicitly focusing on the link between digitalization and societal challenges and the broader need to understand shifts towards challenge-oriented transformative innovation policies, this paper investigates how policies relevant for digital transformations have evolved over time, and for what reasons. We ask the extent to which the evolution of policies conforms

[1]Digitalization is the process of applying digitizing techniques to social and institutional contexts that make digital technologies meaningful in the environment in which they are applied. Digitizing or digitization means the technical process of encoding and conversion of analog data/signals into digital forms. Digitalization therefore entails the development of sociotechnical structures that are mediated by digital artifacts. This conceptual clarification is based on earlier work (Tilson, Lyytinen, & Sørensen, 2010; Yoo et al., 2010)

to or differs from the postulated policy evolution towards challenge-orientation and towards transformative policy rationales. Furthermore, the paper examines why some of the observed patterns tend to be of general nature, while others relate to context-specificities. The investigation covers policy efforts beyond the remit of traditional innovation policy because of the cross-cutting implications of digital technologies and related innovations and because of the call for whole of government approaches in the recent discourse on transformative innovation policy.

We select Rwanda and South Africa, in Sub-Saharan Africa (SSA), as the empirical setting. While digitalization holds promise to deliver economic and social good in the Global North and the Global South, it has recorded an unprecedented speed and impact in the latter. This had meant that developing countries, especially in SSA, have had the opportunity to leapfrog into the digital economy. Conversely, developing countries stand a higher risk of the social costs of digitalization, including the re-enforcement of inequalities and environmental degradation (Popkova, De Bernardi, Tyurina, & Sergi, 2022; O'Sullivan etal., 2021). Previous studies explore issues related to digitalization and sustainability or, in more specific cases, mission-oriented policies and projects, in the energy sector in SSA. For example, empirical work has investigated how the impact of ICTs on environmental sustainability in industry is framed (Kunkel & Matthess, 2020), and the trends in the deployment of digital technologies in the energy sector (Nwaiwu, 2021). Others analyse policy support for business model innovation in off-grid energy development in SSA (Trotter & Brophy, 2022), and a mission-oriented approach to energy transitions in South Africa (Andreoni, Creamer, Mazzucato, & Steyn, 2022), but they are not focused on the coupling between digitalization and sustainability transitions in a broader sense. We represent sustainability beyond "environmental", hence advance the thinking of a multidimensional analysis of the digitalization and sustainability coupling advocated in the literature (Brenner & Hartl, 2021). We link the transformative change thinking to digitalization to advance understanding of how the processes coevolve.

Our empirical study is based on a method in which we calibrated the extent to which economic growth and competitiveness, inclusive development and environmental sustainability are reflected in 38 digital development policy documents. We also developed a matrix of digital development policy elements to explore whether and the extent to which types of policy rationales (technology-push, innovation system building and system transformation) are employed to drive given policy goals. This way we advance understanding of how the policy elements interact. In contrast to the widespread discourse on transformative innovation policy, we find that the policies relevant for the digital transformation have been challenge-driven from the beginning addressing besides economic growth also inclusivity and poverty reduction. Also, we find a potentially generalizable pattern in transformation processes, embarking with system building, then focusing on developing products, processes, and business models, and finally specializing the instruments to address specific shortcomings. These findings complement and contrast existing studies often centred on the Global North and often covering a narrower set of innovation policies.

The rest of this paper is structured as follows. Section 2 presents the literature, in which system transformation policy is linked to digitalization. Section 3 provides the background to the empirical cases, and the method used in the analysis. Section 4 presents the findings about the evolution of

policies relevant for the digital transformation in the two countries. Section 5 discusses the policy evolution with respect to their alignment with shifting societal challenges, and the conditions that shape this coevolution. In Section 6, we conclude, with reflections on how future research and policy may build on this work.

2 Related literature

2.1 Evolution of innovation policy goals and rationales

The discourse on innovation policy has been changing over the years, with a relatively recent shift towards transformative innovation policy or mission-oriented innovation policy (Edler & Fagerberg, 2017; Grillitsch, Hansen, & Madsen, 2021; Kuhlmann & Rip, 2018; Schot & Steinmueller, 2018). The changing discourse captures differing perspectives on the mechanisms through which innovation is contributing to change in society and the change process more generally, as well as the desired policy outcomes. Despite variations in the terminology, Schot and Steinmueller's (2018) differentiation in three frames for innovation policy has received most traction in the literature.

Accordingly, the first frame is labelled as "innovation for growth" and relates to a concern about the development of the industrial economies after World War II (Schot & Steinmueller, 2018). The main idea in this framing was that investments in research and development would result in new knowledge that then would lead to new processes or products taken up in mass markets. Innovation is seen in this framing as commercialized invention underpinned by a linear understanding of innovation process, which is essentially "invention-oriented" (Edler & Fagerberg, 2017). The main policy question in this framing was whether the market would lead to a level of investment in research and development, which was desirable from a social perspective (Arrow, 1962). The economist rationale was that firms cannot appropriate all the positive effects of investments in research and development due to for instance knowledge spillovers and labour mobility and will thus invest less than socially desirable. Hence, policy instruments were developed to subsidise research and development activities and create opportunities for innovators to reap monopolistic rents through for instance patent legislation. However, the link between knowledge generation and knowledge exploitation through innovation, or the impact of these activities on society was not further assessed, largely assuming that this link functions properly through market mechanisms or that any undesirable outcomes could be regulated ex-post. Associated with the first framing are also the early technology-driven missions related to the military industry such as the Apollo or Manhattan programs. For instance, Mazzucato (2015) argues that these investments contributed substantially to economic development through the commercialization of new knowledge.

The second frame refers to the "systems of innovation" perspective developed in the late 80s and 90s (Freeman, 1987; Lundvall, 1992; Nelson, 1993). This perspective was developed in the wake of the crisis in the 70s, the realization of the relatively weak link between investments in research and development and economic growth, and slower than expected convergence in economic performance between countries (Schot & Steinmueller, 2018). It also related to a shift in the perspective on innovation away from a linear, technology-push understanding of innovation towards a recognition of the interactive

nature of innovation processes (Kline & Rosenberg, 1986). From focusing only on knowledge generation (inventions), researchers and policy-makers increasingly paid attention to the link between knowledge generation and knowledge exploitation, for which learning between universities and firms, or between producers and users (von Hippel, 1986) plays a fundamental role. These learning dynamics, it was argued, depend essentially on the institutional environment in which the actors are embedded, which is why the "systems of innovation" frame has also been framed as an "institutional approach" (Grillitsch, Hansen, & Madsen, 2021). Given the focus on the national institutional framework, the systems of innovation frame also connects to the literature on varieties of capitalism (Hall & Soskice, 2001; Vitols, 2001) arguing that liberal market economies like the US provide a more conducive institutional environment for radical innovations in science-based sectors while coordinated market economies like Germany would be better suited to promote interactive learning and incremental innovations in, for instance, engineering sectors. Policies aimed then at building systems of innovation by, for instance, strengthening linkages and generating incentives for learning between actors in the knowledge generation and exploitation system, and policy makers (Autio, 1998), and enhancing the absorptive capacity of firms (Cohen & Levinthal, 1990). The overall policy rationale, however, was complementary to the "innovation for growth" frame, where growth was achieved through enhancing competitiveness by innovation (Schot & Steinmueller, 2018).

The third framing is concerned with "transformative change" and takes its origin from the appreciation that the focus on innovation and growth contributed substantially to both climate change as well as inequalities (Kuhlmann & Rip, 2018; Schot & Steinmueller, 2018). These negative externalities of innovation and growth are perceived as too substantial as to be regulated ex-post. Accordingly, rather than focusing on particular innovations, policy should target the transformation of socio-technical systems (Geels, 2004; Markard, Raven, & Truffer, 2012) or system innovation (OECD, 2015) requiring larger technological, social, institutional, and behavioural changes. Where frame 1 is mainly technology-push and concerned with invention, and where frame 2 incorporates the link between the knowledge generation and exploitation sub-systems and policy, frame 3 is even broader considering the processes and mechanisms through which innovation may contribute to transforming socio-technical systems. To address these broader policy outcomes, a set of transformation failures or challenges need to be addressed (Grillitsch et al., 2019; Kivimaa & Kern, 2016; Weber & Rohracher, 2012). This refers, among others, to incorporating directionality in innovation policy, so that innovation policy not only serves growth but also environmental and social outcomes. Experimentation is highlighted as a process and governance mode through which new system configuration could be discovered and the high-levels of uncertainty addressed (Sengers, Wieczorek, & Raven, 2019). Transformative innovation policy further foregrounds the role of demand articulation and public procurement to create a market, test, and demonstrate green and inclusive innovations (Edquist & Zabala-Iturriagagoitia, 2012; Uyarra et al., 2020). Finally, transformative innovation policy puts higher demands on policy coordination, learning, and reflexivity, which have only relatively recently been investigated in relation to, for instance, the monitoring and evaluation of innovation policy (Haddad & Bergek, 2023; Rohracher, Coenen, & Kordas, 2023).

The scientific discourse on different frames of innovation policy suggests a certain temporality and layering as shown in Figure 1 (Diercks, Larsen, & Steward, 2019). Hence, the "system of innovation" frame would be added onto but not replace the "technology-push" innovation for growth frame. The "transformative change" frame would be the latest layer added on the top of the two previous ones. Over time, the relative importance of the different frames changes, even though all three are expected to play a role today. This is how the evolution of innovation policy is conceptualised in the literature.

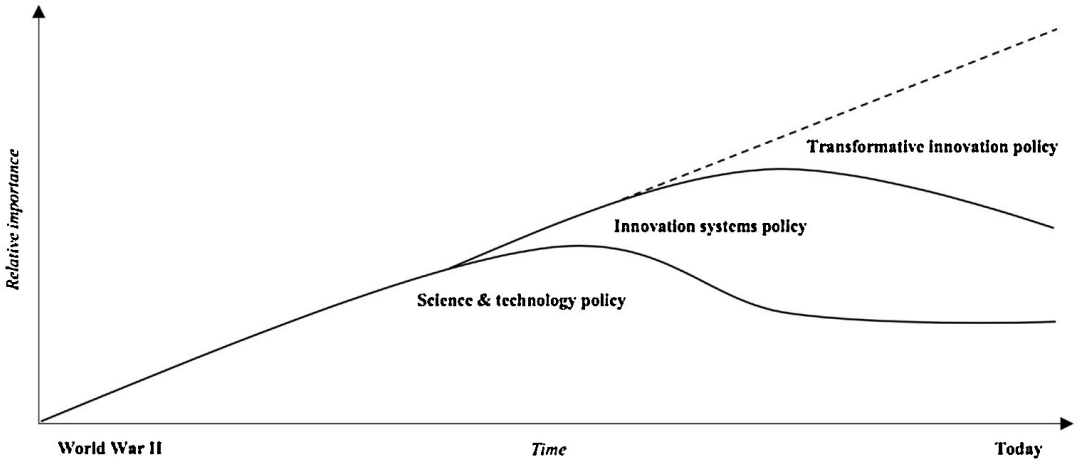

Figure 1: Layering of innovation policy frames

Source: Diercks et al. (2019)

As Diercks, Larsen, and Steward (2019) argue, each of the frames have i) a policy agenda in terms of the policy goals and desired impact, and ii) a certain policy rationale and understanding of the change processes to be influenced with the policy intervention. The three frames of Schot and Steinmueller (2018) combine these two aspects where Frame 1 and 2 are considered to mainly aim at growth while Frame 3 aims at broader societal outcomes addressing also climate change and inequality. However, as argued above, the frames differ in their rationale. We suggest disentangling the policy agenda from the underlying rationale when investigating how innovation policy has evolved over time as shown in Figure 2. This is because a technology-push innovation policy is not necessarily only growth oriented. For instance, the development of hydrogen technologies to decarbonize manufacturing processes can very well serve first and foremost an environmental goal. Also, policies to strengthen innovation systems are not necessarily growth oriented. For instance, building innovation capabilities outside the main metropolitan areas may have a social dimension concerning the fight against interregional disparities. By highlighting different phases in Figure 2, we relate both to Diercks, Larsen, and Steward (2019) and Schot and Steinmueller (2018) suggesting a temporality in the evolution of innovation policy, which is not linear but exhibits some breaks in both policy agenda and rationale.

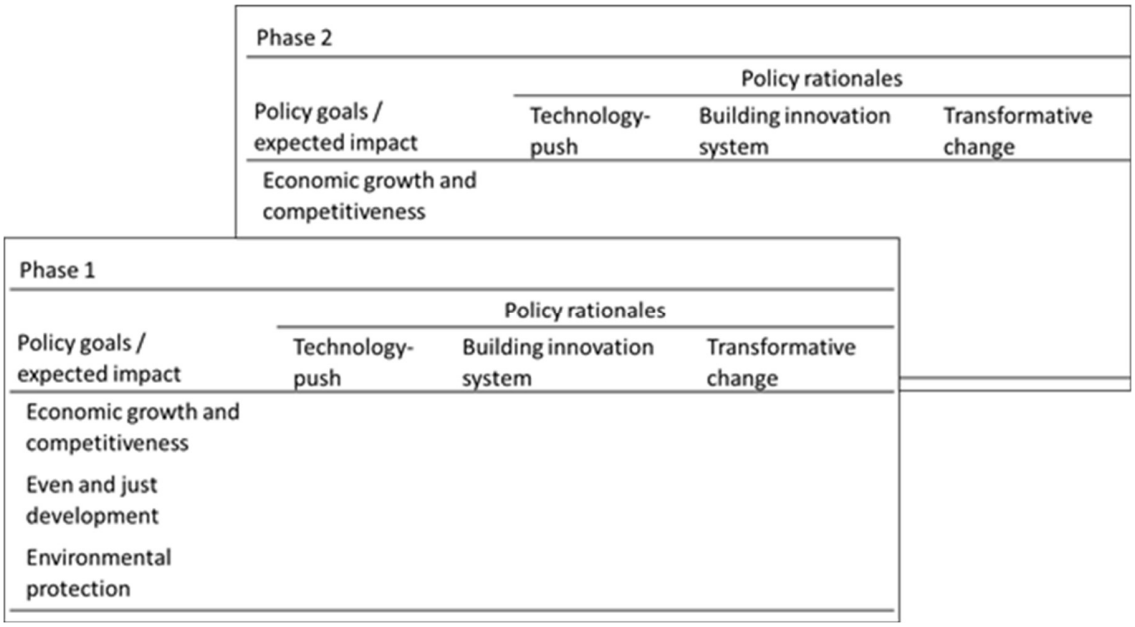

Figure 2: Framework for analysis of the evolution of innovation policy elements and rationales.

2.2 Digital technologies and transformative innovation in developing countries

The adoption and use of digital technologies have contributed to productivity and economic growth and inclusive development as they reduce information gaps in production process, lower transaction costs and increase participation in the global value chains (Dahlman, Mealy, & Wermelinger, 2016; Mayer, 2021). Even though the economic dimension has received the highest attention in the literature, the inclusive development and environmental sustainability effects of ICTs are recognized. For example, a survey of publications on ICT and economic performance by Vu, Hanafizadeh, and Bohlin (2020) finds that the publications have increased consistently since the early 1990s, with a focus on ICT's effect on GDP, sectoral output and firm performance. Asongu, Le Roux and Biekpe (2017) argue that the current state of literature pays less attention to ICT as a policy variable that has the potential to address environmental sustainability concerns such as CO_2 emission and climate change.

Digital technologies have opened opportunities for social networking, knowledge access and innovative entrepreneurial initiatives at difference levels and in different contexts (Nambisan, Wright, & Feldman, 2019). For example, digital finance offers innovative products, and reconfigures the landscape of micro, small and medium enterprises' (MSMEs) access to finance (Sommer & Disse, 2020), as well as household and business access to low-cost energy solutions (Guo, Qi, Wang, & Li, 2023; Razzaq & Yang, 2023). The capabilities of digital finance to open novel opportunities in inclusive and green innovation are linked to business models, which not only foreground broad reach but are also tolerant of small and slow returns.

The benefits of digital advances come at social costs. Digitalization raises questions about the digital divide, and inequality in wages and wealth. For example, the skill-biased nature of digitalization and jobs means that it creates a superstar labor market in which few highly skilled persons receive disproportionate pays while the increasing automaton of routine tasks poses risk to low skill jobs

(Brynjolfsson & McAfee, 2012; Frey & Osborne, 2017). On a promising note, Acemoglu and Restrepo (2019) have argued that the job loss or displacement effect of automation can be compensated for by the reinstatement effect of digital advances, such as the development of new applications, and new job opportunities in the same and related industries. Related to the superstar labor market is the rise of big technology corporations in the digital economy. This has raised concerns about value creation and distribution on digital platforms, ownership and control, data surveillance and privacy (Acquisti, Brandimarte, & Loewenstein, 2020; Alfnes & Wasenden, 2022; Birch & Cochrane, 2022; Zuboff, 2015), as well as the status, contract precarity and wellbeing of digital gig workers (Heeks et al., 2021; ILO, ISSA & OECD, 2023). This is particularly important in developing countries, which face the challenge of developing complementary capabilities and structures to govern the digital economy.

Like the inclusive digital development question, the interaction between digitalization and environmental sustainability presents two sides. On the promising side, communication intensities (telephone, mobile, email, messages and phone apps) coevolve with energy intensities such that they both increase at the initial stage of industrial development, but energy intensity decreases with increasing digitalization of economic activities at a later stage (Fouquet & Hippe, 2022). As digital applications are deployed to replace or complement activities that require manual processes and physical distance, they drive material use, energy consumption and carbon emission downwards (Chen, 1994). Advanced digital technologies are now being adopted to promote green industrial activities in developing countries. For example, Lema and Rabellotti (2023) report similar trends in efforts to green the manufacturing value chains in developing countries, where digital advances are promising but record low adoption rates to date.

On the downside, digital advances such as The Internet of Things (IoTs), Big Data Analytics (BDA) and AI require more computing resources. This means increasing demand for data centers, which drives up energy consumption and offsets energy efficiency gains of the digital advances (Freitag et al., 2021). The energy efficiency gains associated with digitalization drive down cost and increase disposable income which in turn enables users to increase consumption or spend on more unsustainable alternatives (Coroamă & Mattern, 2019; Røpke, 2012). For example, lower Internet and energy costs have potential to free up incomes which can result in the consumption of more digital content and energy through connection of more devices and streaming related to entertainment and media. Accordingly, sustainability-oriented digitalization research and policies will need to take into account direct and rebound effects, as well as incorporate economic behavior and social practices that shape these effects (Brenner & Hartl, 2021; Widdicks et al., 2023; Williams, Sovacool, & Foxon, 2022).

2.3 Digitalization and the challenges of sustainability-directed innovation policies in the African context

Technological advances and economic development in SSA countries are still at an early, in best cases intermediate, stage. This means that there is potential, from scratch, to shape and orient digital development policies towards the coevolution of economic prosperity, inclusive development and green transitions. SSA's technological path is less established and digital, hence presents lower risks of being

locked in old technologies (Amankwah-Amoah, 2019). Flexibility is expected to be higher and green switching costs lower under this condition. Past technologies shape current conditions, which in turn shape future technology and development trajectories (Fagerberg, 2018; Stern & Valero, 2021), as countries with comparative advantage in unclean technologies and industries face difficulties in converting to green competitive industrial activities (Fankhauser et al., 2013). However, SSA's relatively low technological capabilities and slow economic progress present the risk of over-emphasis on economic growth and competitiveness. The pressure to scale up economic growth and technological capabilities could crowd out social and environmental sustainability concerns while technology-push and innovation capability building are deployed as dominant rationales of digitalization policies.

However, economic, social and environmental goals need not be contradictory or mutually exclusive. Rodrik (2014) points to the possibility of green industrial policy design and implementation in which efforts are directed at economic growth and competitiveness, alongside inclusive and green innovation. This is possible, for example, through the creation of green jobs coupled with productivity and economic growth. This resonates with the argument by Stern and Valero (2021) that forward-looking institutional frameworks and policy mechanisms can foster long-term productivity and growth, and deliver inclusive development and zero-carbon transitions. Naudé (2011) reports that in driving energy efficiency, diversification of energy sources and adoption of new technologies, South Africa can create green jobs through activities related to renewable energy. This means that digital development policies have the potential to drive green R&D and related processes towards sustainable outcomes. In line with this thinking, Acemoglu, Aghion and Hémous (2014) present scenarios in which a bundle of regulatory instruments (green taxes and subsidies) can be employed to direct clean technologies in production process. However, weak institutions, poor investment in R&D and general innovation support, and low skill base in SSA countries challenge the working of sustainability-directed technological advances, including digitalization.

3 Research context, material and method

3.1 Research context

The research is conducted in two countries, Rwanda and South Africa. Rwanda shows economic resilience in transitioning through national conflicts in the 1990s and post-war recovery. Its economy has witnessed consistent growth and poverty reduction, albeit significant impact has yet to show across provinces, beyond Kigali (Mckay & Verpoorten, 2016; UNECA, 2021). Access to the Internet in homes, public institutions and businesses shows unequal distributions across space and socioeconomic groups (Mumporeze & Prieler, 2017; Otioma, Madureira, & Martinez, 2019). Although efforts have recorded gains in digital connectivity, the country grapples with developing the complementary infrastructure and skills to support digital transformation. As regards complementary infrastructure, electricity poses a major obstacle, particularly in households in rural communities. Efforts are directed towards expanding limited electricity access in Rwanda through a mix of on-grid and off-grid solutions, which have recorded recent progress, from a modicum of 24% of households connected in 2016 to estimated 55% in 2020, with ambitious 100% connectivity expected by 2024 (Climate Investment Funds, 2022; UNECA, 2021).

The Government of Rwanda has issued successive policies in form of National ICT Infrastructure Plans, and more recently the Smart Rwanda Plan (Ministry of Youth & ICT Rwanda, 2015a, 2015b). IremboGov, created in partnership with Irembo in 2015, provides access to government services and partners with social value-driven actors to reach rural areas with Internet-enabled services. UNCTAD (2014) notes that the ICT sector is at the heart of Rwanda's development efforts therefore has potential to transform it from subsistence agriculture to a middle-income knowledge-based economy. These efforts to develop a modern and technologically inclined economy amidst less favorable economic conditions set it apart for an exploration of the elements of digital development policies, which can have profound impact on the path, speed and scale of economic progress. In working towards economic and technological progress, marked by its goal to attain a middle income economy status by 2050, Rwanda envisions harmonizing economic growth and green transition (Ministry of Environment Rwanda, 2019).

South Africa is a leading economy in SSA and serves as the economic gateway to Southern Africa(Scholvin & Draper, 2012). South Africa's middle-income economy has a relatively good infrastructure and industrial development in SSA. However, it is struggling with high unemployment, historic inequality and a stagnating economy, with the risk of entrenchment in hard-to-decarbonize industrial activities, especially in mining (Andreoni, Creamer, Mazzucato, & Steyn, 2022; Bundy, 2020; Francis & Webster, 2019). These conditions point to the need to explore policy options, including leveraging digital technologies, to address multiple dimensions of development.

The Government of South Africa has issued policies in the domains of digital development, including the National Broadband Strategy and related initiatives aimed at advancing digital skills, to adapt to technological change (Department of Communications and Digital Technologies, 2020; Department of Communications, 2013). It remains unclear how policies aimed at digital technology development have been directed towards achieving the broader goals of economic prosperity and social good. Digital technologies can replicate and consolidate old inequalities or bridge the divides, depending on how their applications are directed. This is important for South Africa which has historical inequality and high unemployment rates. Digital advances have taken course in public service delivery and across business sectors, as evident in the adoption of robotics and related AI solutions (Anzolin & Andreoni, 2023; Department of Telecommunications and Postal Services, 2016).

3.2 Material and method

This empirical study grounds on a comprehensive study of policy documents in the two countries, covering 2000 to date in Rwanda and 1996 to date in South Africa. The search for policy documents considered two groups of policy development and implementation bodies to capture the specialized but cross-cutting nature of digital development policies. The first group comprises the primary Ministries, Departments and Agencies (MDAs) with ICT policy mandate, whose specific names vary across countries. The second group includes complementary MDAs whose work is related to the broader ICT agendas of the countries and/or who, in some cases, develop customized policies to drive digital technology use in their domains. These include infrastructure and environment, industry and finance, and education and social development.

We identified central online repositories to find relevant MDAs and searched their websites through links such as “resources”, “publications”, “projects”, “programs” and “initiatives”. We formulated terms to direct our search, identification, and screening of relevant policies. The key terms include “digital(ization) policy/plan/strategy/project”, “ICT development policy/plan/strategy/project”, and “Cybersecurity policy/plan/strategy/project”. We also used synonyms such as “law”, “act”, “blueprint” and “whitepaper” that are related to digital/ICT/Cyber development. We included cybersecurity-related policies because governing the risks associated with the use of digital platforms, data and services is critical to economic competitiveness, inclusion, and environmental sustainability. Although we kept the search terms open to accommodate diverse policy titles in the domain of ICT and development, we were not interested in a deep dive analysis of the implementation of specific programs, projects, and plans. We included policies that address one or more elements of economic growth and competitiveness, inclusive development, and environmental sustainability, as well as provide scope to understand the rationales behind the elements or mechanisms for driving the elements. We excluded documents such as guidelines that have a narrow focus, for example, relating to the use of ICT in a specific MDA. The search and screening yielded a total of 38 policies, comprising 23 in Rwanda and 15 in South Africa (Appendix A1).

Having identified the digital development policies, we studied the documents to establish whether and to what extent each addressed the elements under consideration (goals/impacts and rationales). We built on an earlier implemented methodology (Grillitsch et al., 2022) to categorize the extent to which the elements of interest are reflected in the documents (a scale of 0 to 1; Table 1; See also Fig 2). In further analysis, we developed a matrix of policy elements, complementing our calibration with a related categorization based on earlier work (Edler & Fagerberg, 2017; Edler, Gök, Cunningham, & Shapira, 2016), to explore the extent to which types of rationales are employed to drive given policy goals. The clustering of a type of rationales around given policy goals shows the extent to which the former is employed to drive the latter. This is important, as it provides insights into how technology-push rationales, for example, are aligned with inclusive and green development.

4 Findings

4.1 Evolution of digital development policies in Rwanda

Digital development policies have evolved in four phases in Rwanda covering: the regulatory capacity and infrastructure foundation phase (2000-2005), the infrastructure expansion phase (2006-2010), the service development phase (2011-2016), and the data revolution and cybersecurity phase (2017-today). Each phase is analyzed below.

4.1.1 The regulatory capacity and infrastructure foundation phase (2000-2005)

At the start of the 2000s Rwanda laid the groundwork for digital development through its ICT-led socioeconomic development policies. This period witnessed the launch of foundational digital development policies and strategies aimed at providing the basic infrastructure to drive ICT access and adoption. Considering the promise of economic growth and development that the digital turn in the early 2000s held, the digital development policies put high emphasis on economic growth and competitiveness as well as inclusive digital development. This element is visible in the choice of name of

the major policies of the time, “ICT-led Socioeconomic Development Policies/Plans”, which presented opportunities to drive economic activities and reduce poverty through the expected mass adoption and use of mobile phones, computer and the Internet and related services.

While the economic and inclusive development goals and impacts were top on the agenda of the first phase, the component of environmental sustainability received minor reflections. The high emphasis on economic growth and inclusive development was matched with strong technology-push and innovation system strengthening. This way the country planned to invest in technology adoption, Research and Development (R&D) and institutional capacity building. This means coordination and knowledge sharing among relevant actors in public, private and research/training organizations, including universities.

The challenge of technology change and institutional adjustment to the new era had meant that specialized structures were required to support policy development, regulation, and implementation. Accordingly, the Rwanda Utilities Regulatory Authority (RURA) was formed in 2001, with a mandate to regulate the ICT sector, among others (water, energy and transport). This period mapped out the framework to build the requisite infrastructures and regulations to support connection to and use of digital technologies.

4.1.2 The infrastructure expansion phase (2006-2010)

Having laid out the initial strategy to connect its population and socioeconomic activities to ICTs and govern such activities, Rwanda moved towards driving mass adoption of digital technologies through the expansion of ICT infrastructure. The second phase builds on the goal of phase 1 aimed at establishing a knowledge-based economy over the next 20 years. In this phase, Rwanda emphasized strengthening its economic base and enabling environment to drive a knowledge-based economy. The emphases on economic competitiveness and inclusive development remained as the country strove to leverage ICTs in productive activities and connect populations across regions. Accordingly, this phase of Rwanda’s digital development prioritized digital infrastructure expansion to connect people and regions, and promote economic growth, employment creation and poverty reduction.

This phase is similar to the start of the 2000s in its emphasis on economic growth and competitiveness but differs in two ways. First, it progressed the previous phase through strengthening the network infrastructure drive and inclusion. With universal and affordable access at its core, it prepared for the dawn of electronic citizen service (e-government) and e-business. Second, it provided better scope for green ICTs, outlining the plans to establish and develop environmental ICT resources such as Geographic Information Systems (GIS) and early warning capabilities to be deployed in infrastructure, agriculture and national statistical production, among others, aligning the intentions of Rwanda’s ICT for Development (ICT4D) and ICT 2020 agendas. In its drive towards universal and affordable network infrastructure access, ICT resource centres and strong economic base, the Rwanda Information Technology Authority (RITA), and the Ministry of Infrastructure and Ministry of Lands, Environment and Natural Resources were required to coordinate with relevant partners and one another. Considering the spike in the environmental component alongside the expected economic and social inclusion outcomes of this phase (Table 1), it represents a recognizable transformative regime in the digital development of Rwanda.

4.1.3 The service development phase: Platform-enabled services (2011-2016)

While Rwanda's previous phase had incorporated ICT resource centres and e-government services, such service development and penetration had yet to be embedded in citizen services and the economy at visible thresholds. The earlier National ICT Infrastructure Initiatives (NICIs), for example NICI-2 (2005-2010), had estimated that the early to mid-2010s would be dedicated to service development required to facilitate and sustain economic growth and national prosperity.

This phase witnessed the rise of specialized policies and programs designed to integrate digital services into the economic and social life and, most remarkably, government service delivery in Rwanda. While earlier policies were essentially broad-based socioeconomic development documents led by ICT, this phase focused on specific policies to develop digital skills, entrepreneurial activities, and platform-enabled government services, as represented by the ICT in Education and Digital Talent Policies (Table 1).

The increasing digitalization of government services and business for which the earlier digital access and adoption had paved the way challenged the existing telecommunication infrastructure, particularly Internet speed. Considering the size and speed of ICT adoption and use in homes, public institutions, and business establishments, specialized broadband policies for high-speed Internet and Internet-enabled services emerged in this phase. For example, not only did the service development phase witness the introduction of the National Broadband Policy for Rwanda in 2013 (a clear definition of the need for high-speed Internet) and Smart Rwanda Master Plan in 2015 (a symbol of integrated platform services and knowledge-based economy) but also a concrete major e-government service platform, IremboGov, in 2015.

4.1.4 The data revolution and cybersecurity governance phase (2017-to date)

The fourth phase consolidated efforts initiated in the service development phase. It emphasized the data revolution. Data revolution meant that Rwanda would leverage IoT and BDA to create economic and social value.

The economic growth and competitiveness orientation, as well as technology-push and coordination of actors in the innovation system remained strong. Key policies such as the Data Revolution, and ICT Sector Development Plan and the Fin-tech Policies prioritized economic growth and competitiveness, and inclusive development components. The development of e-commerce, e-government, digital finance, and cloud-based services comes with increased cybersecurity risks of IT-integrated business process and services. Therefore, Rwanda made deliberate efforts not only to recognize cybersecurity risks but also to establish specialized institutional structures to govern the risks of integrated electronic transactions.

A government agency to lead the governance of cybersecurity, and the Child Online Protection (COP) Policy are a pointer to prioritizing the protection of a vulnerable segment of society to participate in the digital economy. The digital security and finance drive of this phase highlights the intensive efforts at leveraging digital technology advances in economic competitiveness and governing the associated risks. The data revolution and cybersecurity governance phase witnessed the return, although on a moderate

scale, of the environmental sustainability agenda in Rwanda's digital development, with potential to channel financial technology and related initiatives towards green innovation.

Table 1: Phases in the digital development policies in Rwanda and South Africa

Country	Phase	Years	Goal/impact orientation	Rationale orientation	Summary of policy elements (goal/impact and rationale)	Major theme
Rwanda	Digital regulation capacity and infrastructure foundation	2000-2005	High *EGC, High EJD, Minor-Moderate EP	High tech push, High IS, Minor system transformation	Strong technology and innovation capabilities building directed towards economic progress and inclusive development.	Regulation, infrastructure (kick-off enabling environment), socioeconomic development
	Infrastructure expansion	2006-2010	High EGC, High EJD, High EP	High tech push, High IS, Moderate system transformation	Strong technology and innovation capabilities building moderated by system transformation for economic progress, inclusive development and green transitions.	Infrastructure, socioeconomic development
	Service development phase	2011-2016	High EGC, Moderate-High EJD, Minor-EP	High tech push, Moderate-to-high IS, Minor system transformation	Strong technology and innovation capabilities building directed towards economic progress and inclusive development.	High speed Internet, skills development, e-services
	Data revolution and cyber security governance phase	2017-date	Moderate-High EGC, High EJD, Moderate EP	Moderate-High tech push, Moderate-High IS, Moderate system transformation	Strong technology and innovation capabilities building moderated by system transformation for economic progress, inclusive and green transitions.	High speed Internet, cybersecurity governance, digital finance technology, Big data and cloud services (advanced e-services)
South Africa	Regulatory capacity, infrastructure and basic service development phase	1996-2002	Moderate-High EGC, High EJD, Minor EP	Moderate-High tech-push, Moderate IS, Minor system transformation	Technology and innovation capabilities building directed towards economic progress and inclusive development	Regulation, infrastructure, universal access
	The broadband service and Information Society phase	2003-2012	High EGC, High EJD, Moderate EP	Moderate-high tech-push, High IS, Minor system transformation	Strong technology and innovation capabilities building directed towards economic progress and inclusive development.	High speed Internet, e-commerce, general e-service, inclusive ICT sector, SMMEs
	The digital industrial revolution era	2013-date	High EGC, High EJD, Moderate EP	High tech-push, High IS, Moderate system transformation	Strong technology and innovation capabilities building moderated by system transformation for economic progress, inclusive and green transitions.	High speed Internet, digital skills and future of work, **Industry 4.0, advanced e-service, cybersecurity,

*Economic growth and competitiveness (EGC), Even and Just Development (EJD), EP (Environmental Protection), Innovation System (IS)

** Industry 4.0 refers to the networked embedding of devices, technologies, production facilities and related infrastructures across all parts and stages of industrial production to make the interaction between humans, machines, and products productive, efficient, and flexible. Industry 4.0 is data-driven and enabled by a cyber-physical system, which is the merger of the digital and physical components (Brettel, Friederichsen, Keller, & Rosenberg, 2014; Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014; Reischauer, 2018).

Table 2: Interaction between policy elements (goals/impacts and rationales) in Rwanda

Policy element	Rationale	Technology push				Innovation system building				Transformative change			
Goal/impact	*Significance of elements	■■■ (1)	■■□ (0.67)	■□□ (0.33)	□□□ (0)	■■■ (1)	■■□ (0.67)	■□□ (0.33)	□□□ (0)	■■■ (1)	■■□ (0.67)	■□□ (0.33)	□□□ (0)
Economic growth and competitiveness	■■■(1)	●●●●●●●●	●●●●	●		●●●●●●●●●	●●●●			●	●●●●	●●●●●	●●●
	■■□(0.67)	●●	●●●			●●●	●	●		●		●●	●●
	■□□(0.33)	●	●	●		●		●	●		●	●	●
	□□□(0)	●		●		●			●			●●	
Even and just development	■■■(1)	●●●●●●●●	●●●●	●	●	●●●●●●●●	●●●●		●●	●●	●●	●●●●●●●	●●
	■■□(0.67)	●●●	●●			●●●●	●				●●	●●	●
	■□□(0.33)	●	●	●●		●		●●	●		●		●●●
	□□□(0)												
Environmental protection	■■■(1)	●●	●	●		●●●			●	●	●●	●	
	■■□(0.67)	●●●				●●	●			●	●	●	
	■□□(0.33)	●●●●	●●●			●●●	●●●	●		●		●●●●●	●
	□□□(0)	●●●●	●●●	●●		●●●●●	●	●	●●		●	●●	●●●●●●

■■■: Major relevance (1) ■■□: Moderate relevance (0.67) ■□□: Minor relevance (0.33) □□□: No relevance (0)

* Authors' calibration; description of relevance of elements are also aligned with Edler and Fagerberg (2017) and Edler etal (2016)

One thick dot represents a policy document. However, this distribution is not used in strict quantitative sense but the show the general pattern of orientation of rationales towards driving the goals and impacts related to economic growth and competitiveness, inclusive development and environmental sustainability.

Table 3: Interaction between policy elements (goals/impacts and rationales) in South Africa

Policy element	Rationale	Technology push				Innovation system building				Transformative change			
Goal/impact	*Significance of elements	■■■ (1)	■■□ (0.67)	■□□ (0.33)	□□□ (0)	■■■ (1)	■■□ (0.67)	■□□ (0.33)	□□□ (0)	■■■ (1)	■■□ (0.67)	■□□ (0.33)	□□□ (0)
Economic growth and competitiveness	■■■(1)	●●●●●●●	●●●	●		●●●●●●●●●	●●			●	●●●●	●●●●●	●
	■■□(0.67)	●					●						●
	■□□(0.33)		●	●	●		●	●●				●	●●
	□□□(0)												
Even and just development	■■■(1)	●●●●●●	●●●●	●●		●●●●●●●●	●●●	●		●	●●●●	●●●●●	●●
	■■□(0.67)	●					●					●	
	■□□(0.33)	●			●		●	●					●●
	□□□(0)												
Environmental protection	■■■(1)	●	●			●●					●	●	
	■■□(0.67)	●●				●●				●		●	
	■□□(0.33)	●●●	●●			●●●	●	●			●●	●	●●
	□□□(0)	●	●	●●●		●●	●●	●			●	●●	●●

■■■: Major relevance (1) ■■□: Moderate relevance (0.67) ■□□: Minor relevance (0.33) □□□: No relevance (0)

* Authors' calibration; description of relevance of elements are also aligned with Edler and Fagerberg (2017) and Edler etal (2016)

One thick dot represents a policy document. However, this distribution is not used in strict quantitative sense but the show the general pattern of orientation of rationales towards driving the goals and impacts related to economic growth and competitiveness, inclusive development and environmental sustainability.

4.2 Evolution of digital development policies in South Africa

In South Africa digital development polices evolved in three phases: i) the regulatory capacity, infrastructure, and basic service development phase (1996-2002), ii) the broadband service and information society development phase (2003-2012), and iii) the digital industrial revolution phase (2013-today). The phases are assessed below:

4.2.1 The regulatory capacity, infrastructure, and basic service development phase (1996-2002)

South Africa laid the groundwork for modern digital development in the mid-1990s. The Telecommunication Act of 1996 was one of the most significant enablers of regulatory control, industry development and provision of universal access to telecommunication services. It prioritized inclusive development through the promotion of ownership and control of telecommunication services by persons from historically disadvantaged groups, as well as empowerment of women and SMMEs in the telecommunication industry. The Telecommunication Act established the South African Telecommunications Regulatory Authority (SATRA) as the industry regulatory body, and the Universal Service Agency to promote telecommunication service access to all persons, areas, and communities as part of the Reconstruction and Development Program Fund Act, 1994.

Building on the Telecommunication Act, the State Information Technology Agency Act of 1998 (SITA Act) established SITA to coordinate government's information technology resources and promote efficiency and interoperability in service delivery. SITA became an early digital technology powerhouse of the government through the provision of capacity building to other government agencies, especially in training and research, department-specific and interoperable IT applications, software development and maintenance.

By the early 2000s, South Africa had developed regulatory capacity and technological capabilities for commercial and non-commercial electronic services. For example, the Independent Communications Authority of South Africa (ICASA) was established in 2000 through the merger of SATRA and Independent Broadcasting Authority (IBA) (ICASA Act, 2000). The Electronic Communications and Transactions Act, 2002 was enacted to promote an enabling environment for understanding, acceptance and growth of electronic communications and services among the consumer, business and the Government, taking into account the need of all people, areas and communities. Although South Africa prioritized economic growth and competitiveness and inclusive development, its digital development efforts at this stage reflected minor environmental sustainability orientation in the goals and expected impacts.

4.2.2 The broadband service and information society development phase (2003-2012)

The Electronic Communications Act of 2005 points to South Africa's effort towards the convergence of information technologies and provisioning of new electronic communications networks and services. It opened a new path to advancing the country's ICT and development journey. The drive remained

focused on facilitating universal and affordable connectivity and services for all, ICT sector development and stability.

The increasing ICT adoption and services presented new hopes and challenges for building an information society. Accordingly, two related policy efforts became necessary to live up to the changing times, shaped by local demand and global trends. First, the Broadband Infraco was established in 2007 as a state owned company (SOC) to support the drive for expansion and affordability of broadband and electronic communications services in South Africa. This was aimed to promote broadband expansion across and in coordination with regions and communities in a manner that prioritized digital inclusion and national interest. Established by the Broadband Infra Act of 2007, it drew inspirations from the Electronic Communications Act of 2005. Second, the government developed and launched the Broadband Policy for South Africa in 2010 to advance efforts towards providing accessible, universal and affordable high-speed Internet to citizens, business, communities and government for economic growth and related societal benefits. This was recognized as an effort towards the formation of an information society in line with global digital technological requirements and trends. The Broadband Policy for South Africa pointed out that the South African Government approved the building of an information society in 2007 in line with the United Nation's World Summit on Information Society (WSIS), which resolved that ICT infrastructure is an essential foundation for the Information Society.

This phase remained consistent in the pursuit of competitive and inclusive digital development in South Africa. For example, the Electronic Communications Act prioritized the advancement of efficient and inclusive communications networks and service provision, and inclusive ICT sector development for economic growth and social development. The goal and impact orientation was matched with high technological capabilities building, for example, a clear direction towards research and development in the ICT sector as specified in the Electronic Communications Act. The Broadband Policy of 2010 emphasized economic growth, people-centered and development-oriented information society.

The effort at mainstreaming the Broad-based Black Business Economic Empowerment (B-BBE) into the development of the ICT sector through the B-BBE ICT Sector Code represents the significance of inclusive digital development in South Africa. Although adopted and gazetted in 2012, the B-BBE ICT Sector Code preoccupied the ICT sector and enterprise development discourses from mid-2000s when its working group was formed. This way it framed and pursued inclusive digital development, not only as a social inclusion priority and mechanism but also through economic inclusion embedded in productive activities. Another important aspect of the B-BBE ICT Sector Code is that it highlights policy alignment and coordination between the principals of ICT policy development and regulation and those of private sector and industrial policy development, especially the Department of Trade and Industry, which is the principal of B-BBE and the B-BBE ICT Sector Code.

While this period recorded a moderate reflection of environmental sustainability in the drive for broadband-enabled services and information society building, it made fewer efforts at concrete and deliberate green technological innovations in the process. For example, digital development policy narratives recognized the need to observe environmental/spatial planning standards in the process of building electronic communications networks such as fiber optic cables, satellite systems, mobile

stations and electricity cables that support electronic communication services (Electronic Communications Act 2005). That said, this phase lacked clear policy articulation and deliberate programs related to promoting digital technologies in the development and implementation of green innovations such as circular economy and climate change initiatives.

4.2.3 The digital industrial revolution phase (2013-to date)

Digital development policies of this phase drew inspirations from the New Growth Path (2010) and National Development Plan 2030 (2013), which laid out the ideals, development priorities, policy directions and interventions that could shape economic, social, technological, and broader development path of South Africa. In this phase, the digital development policies of South Africa were developed and coordinated towards consolidating the goals of an advanced information society. The National Development Plan 2030 had laid the groundwork for the broader picture of South Africa's economic future up to 2030, with priority on the role of the knowledge economy in the pursuit economic and social progress through job-rich growth, poverty eradication, equity, and social cohesion.

The NDP 2030 placed ICTs at the core of economic and social change through the promotion of universal, high-quality and low-cost communication systems to meet the need of citizens, business and the public sector. Therefore, the National Broadband Policy (NBP) responded to the changing need for broadband services and the constraining impact of cost on the rapid deployment of such network infrastructure and services.

In a similar vein, the Integrated ICT White Paper positioned the Government's overall policy efforts to refine existing institutional frameworks and develop technological capabilities for a digital society and digital industrialization. For example, efforts were intensified to reform the ICT sector through the promotion of service-based competition and reduction in market entry barriers to increase consumer choices, promote innovation and reduce cost.

The Government intensified efforts to integrate ICT in its industrialization and reindustrialization programs through policy and regulation, research, development and innovation funding, and skills development. Key interventions include the Department of Science and Technology's (DST) ICT Research, Development and Innovation Roadmap and coordination with the Department of Trade and Industry (DTI), especially in line with the Industrial Policy and Action Plan 2014/2015.

The Department of Telecommunications and Postal Service (DTPS)/Department of Communications (DoC) and DST were required to coordinate to promote ICT R&D investment and planning, as well as mainstream intellectual property (IP) issues as drivers and constraints of ICT sector development. For example, the need for creative common licensing to open the ICT innovation ecosystem while working within IP laws and establishing digital innovation hubs engaged stakeholder discourses in this phase (ICT White Paper, 2016).

In positioning itself for the dawn of digital industrial transformation, South Africa's digitalization policies in this phase had progressed beyond widespread diffusion and use of ICTs. The discourses had advanced towards developing the ICT sector value chains through the enhancement of local capacity to produce ICT equipment and services, as well as consolidate digital innovation and growth of the other sectors of

the economy. In the digital industrial revolution phase, local production was required to not only complement ICT product import and promote value added services but also compete in industry 4.0.

Disruptive digital technologies such as AI, IoT and BDA come with opportunities for seamless connection of things, people and processes as desired in the Information Society. However, there is the challenge of advanced skills as digital advances render existing skills obsolete and open new demand. The National e-Strategy for South Africa (2017) recognized this need and emphasized the component of advanced skills development that would shape the turn of the 2020s. Consolidating previous policies, the National Digital and Future Skills Strategy 2021-2025 (2020) took a specialized step towards digital skills development needed to adapt to and leverage the opportunities of industry 4.0.

The high emphasis on the components of economic growth and competitiveness, and inclusive development was consistent while environmental sustainability was largely confined to maintaining environmental, planning and safety standards in this phase. Although GIS had been emphasized in advancing technological capabilities for rapid broadband network and related service deployment, it was mainly framed as a tool for data management and automation of service delivery. That said, there were promising efforts that could form the basis for clearer articulation and stronger alignment with green and system transformative innovations. The National e-strategy South Africa, for example, highlights aspects that hold potential for mainstreaming green industry and system transforming innovations in digital industrial revolution. These include the potential to develop and deploy wireless technologies that increase efficiency through process automation in manufacturing, and digital applications for smart solutions in transport, energy, and agriculture.

5 Discussion

5.1 General and shared pattern of the evolution of digital development policies

We set out to unpack the extent to which the elements of economic growth and competitiveness, inclusive development and environmental sustainability are reflected in digital development policies. We explore the underlying rationales and how, alongside the articulated goals and impacts, they can be (re-) aligned with transformative change.

We find that digital development policies in both country cases have an explicit and time-consistent foci on economic growth and competitiveness and inclusive development. The drive is to leverage digital technologies for efficiency in communication, service delivery and business process improvement. Early inclusive efforts were centered on providing universal service access to citizens, including those in underserved and unconnected areas, where the budding network infrastructure had yet to reach. Digital literacy and small business empowerment formed the key early value creation policy themes and initiatives aimed at digital inclusion. The turn of the 2000s witnessed broader themes of socioeconomic development, with growth and inclusion at the core.

The digital development policy themes have become specialized overtime. The themes have evolved from an explicit focus on infrastructure and broader regulatory capacity building through a phase

emphasizing the digital society, marked by advancement of e-government, to a specialized era of digital talent, digital services/industry 4.0, and cybersecurity risk governance. While the specialized themes were incorporated into earlier broad-based digitalization policies in both countries, recent adaptive and forward-looking efforts have resulted in the development of specialized policies.

Environmental sustainability has always been incorporated into digital development policies in both countries but lacks the traction that characterizes economic growth and inclusion, though in recent policy documents, elements of green ICT and the green economy tend to be gaining foothold (Tables 1 and 2). Both cases show an explicit and strong focus on the coordination of technology-push and innovation system capabilities building rationales to achieve economic growth and inclusive development. However, there is only a loose orientation of rationales towards environmental sustainability challenges such as climate change, energy consumption and clean technologies.

The observed digital development policy discourses on investment in ICT R&D, skills development, institutional collaboration, and knowledge transfer in the digital economy revolve around efforts to become a regional hub in the knowledge economy. The narratives are centered on the need to drive economic growth and global competitiveness through efficient production processes, raise local shares and integration in the digital value chains, as well as attract investment opportunities to create jobs and a prosperous economy.

5.2 Context-specific patterns

The two cases are marked by several differences. First, South Africa's digital development policies show an early coevolution (or a closer overlap) of telecommunication infrastructure and basic digital services, dating back to mid-2000s. This trend continued through the turn of the 2010s, after it had developed stronger infrastructure capacity, including foundational broadband policy and related initiatives. Conversely, Rwanda entered the 2000s with the priorities of laying telecommunication network infrastructure and regulatory capacity to exploit and govern the emerging opportunities and challenges of the digital economy. The development of services followed later in concrete terms. This reflects the country's projected sequence of digital development, which was to grow from the establishment of an enabling environment through infrastructure development to service development and consolidation (Ministry of Youth & ICT Rwanda, 2015a; The Government of Rwanda, 2001). In addition, the ability to combine digital infrastructure and service development in South Africa reflects its relative advantage as compared to Rwanda in infrastructure development, the presence of well-established telecommunication network operators, as well as network and scale economies (Robb & Paelo, 2020).

Second, South Africa's digital development policy efforts in the recent phases, especially from mid-2010s, tend towards leveraging digital advances for industrial development, with focus on manufacturing, including ICT equipment. This way it seeks to raise its share in the digital value chains and consolidate its position as a regional industrial hub. There is a strong emphasis on critical skills to adapt to the changes and risks of skills obsolescence associated with digital advances such BDA, AI and machine learning (ML). It prioritizes local industrial capabilities building to strengthen weak links in the value chains as regards the development of technologies and applications (Department of Communications and Digital Technologies, 2020; Department of Telecommunications and Postal

Services Republic of South Africa, 2016). While Rwanda equally sees opportunities in digital industrialization, it has clear and directed policy efforts towards a service economy. Its specialized policies targeted at digital talent and financial services show a strategic path of service sector consolidation. This digital development orientation reflects its broader and most recent development priorities, which are summed up in the National Strategy for Transformation 2017-2024 (The Government of Rwanda, 2017). The NST is built on the pillars of economic, social and governance transformation, with services recognized as the core of competitive advantage. NST is directed towards a service-led and knowledge-based economy, in which it expects a major shift in Rwanda's export to be led by high-value financial services, Business Process Outsourcing (BPO) and professional services, among others.

Third, Rwanda has adopted a specialized approach to the governance of digital transformation risks. It has intensified policy and regulatory efforts at adapting to and addressing cybersecurity risks. As the risks associated with the digital economy intensifies, Rwanda has developed targeted regulations and implementation agencies in line with the changing landscape. While such policies and regulations are equally present in South Africa, they tend to be embedded in more complex structures, and are thus less flexible. The differences in national context conditions provide some insights into the observed patterns in cybersecurity policies. South Africa and Rwanda are democratic states, albeit the latter has consistently re-elected the same president since 2000. Being a smaller country, security is under the strong command of a longstanding administration in Rwanda. The tight security coordination and crime monitoring in Rwanda tend to have been translated into the cybersecurity policy and regulation space. Rwanda has a better general criminality score (University of Peace, 2022) and cybersecurity outlook (International Telecommunication Union, 2021). In South Africa, strong inter-agency rivalries and weak coordination may make cybersecurity policy design and legislation difficult (Sutherland, 2017).

As regards challenge-orientation, the observed patterns of digital development reflect contextual economic, technological, historical, and institutional conditions (including broader policy discourses). The prioritization of social and economic inclusion, as well as competitiveness, shows that digital technologies are considered tools for driving growth in the countries where economic growth, poverty and inequality have remained developmental challenges. The historical inequality in South Africa had meant that the Reconstruction and Development Program Fund (The Republic of South Africa, 1994), which aimed to address apartheid-linked social and economic inequalities, and the Growth, Employment and Redistribution Strategy (GEAR) 1996, aimed at addressing fiscal constraints, shaped the overall policy discourses at the time (Le Roux, 1997; Michie & Padayachee, 1998; Mikhaylov, 2018). Early digital development policies in South Africa (1995-2002) reflect this interaction.

A similar pattern unfolds in Rwanda where broader economic policy discourses were hinged on economic development and poverty reduction in which ICTs could serve as a formidable tool. This is strongly reflected in NICI I-III which draws inspirations from broader economic development strategies; namely, Rwanda Vision 2020 and Economic Development and Poverty Reduction Strategies 2007 and 2013. These policies prioritize poverty reduction, alongside human capital development and private sector-led growth. The interaction between ICTs and development conditions in these cases agrees with the thinking that early efforts at ICT deployment in developing countries fit the case of new technologies

looking for applications, on the one hand, and development policies and programs looking for tools of implementation, on the other hand (Heeks, 2008). Digital development policies in the new era reflect more advanced discourses in development, which are oriented towards economic and technological transformation.

5.3 Opportunities and directionality of digital development

The twin digitalization and service economy development in both countries, especially Rwanda, requires not only technical upskilling but also the development of social and creative skills that enable people to complement rather than compete with computers. However, we note that digitalization, being at an elementary stage in African cases and interacting with informal structures, has potential to propel generative effects on jobs. Apart from aligning with the argument that digitalization has job-generating and re-instating effects to compensate for its displacement effect (Acemoglu & Restrepo, 2019), digital development policies and initiatives directed at talent development, entrepreneurship and employment creation in African contexts can promote inclusive job opportunities. The inclusive opportunity effect of ICT infrastructure and value-creation in SSA contexts is in line with the findings of Suri and Jack (2016) based on the case of Kenya. The authors report that mobile money has contributed to reducing poverty and inequality through app-related jobs in the form of mobile money agents.

Digital advances such as robotics, IoT, AI, BDA and additive manufacturing, as particularly espoused in South Africa's recent digitalization and related industrial policies, can aid system and process automation, integration, monitoring and optimization. That said, South Africa faces greater challenges than opportunities in the digital industrial revolution in the short term. This is due to changing demand for skills, dual economic structures (divided traditional primary and tertiary activities) and weak technological conditions evident in poor tooling development support for industrial production, which is under severe strains (Department of Trade and Industry, 2018). In the current era, South Africa's digital development policy efforts are oriented towards plugging into the manufacturing value chain opportunities, including ICT equipment manufacturing and automotive. This has the potential for employment creation and competence building. It also means the potential to produce and provide the requisite digital infrastructure and competence to drive low-energy industrial transformation through greening the manufacturing value chains; a promise reflected in Lema and Rabellotti (2023), but which did not show prominently in the South African policy documents. Apart from the challenge of technological capabilities competence building, green transition initiatives are contested where vested interests in current energy regimes pose an obstacle to clean energy reforms and green industrial activities, as is the case of South Africa (Andreoni et al., 2022). Considering that ICT product life cycle is difficult to track, the goal of ICT deployment and production needs to incorporate the development of complementary capabilities and structures to implement and govern the complex process and system of industry 4.0 and reflect on its environmental implications.

6 Conclusions

Digitalization is conceptualized as a major driver of transformation, in the case of South Africa from industry 3.0 to industry 4.0, and in the case of Rwanda from an agricultural society to a knowledge-based service society. This relates to different preconditions with South Africa having a strong

manufacturing base, which Rwanda is largely lacking. In this respect, many countries in SSA are more similar Rwanda in their preconditions. On the other hand, South Africa is one of the leading countries in the BRICS context in relation to digitalization and automation in industry.

This transformation driven by digitalization from the very beginning targeted both economic and social outcomes. The desired economic outcome aiming at increased competitiveness and growth, however, has to be seen in another light than in the high-income economies. In Rwanda, economic development is about post-war recovery and essentially about fighting poverty and providing decent opportunities for work and income generation, moving up from the group of low-income to middle-income countries. In South Africa, which is a middle-income economy and gateway to SSA, pathways for addressing multiple development dimensions, such as economic stagnation, high unemployment, and historic inequalities, were sought after. Economic and social outcomes have been twin objectives given similar and high priority in the policy documents.

In the case of Rwanda and South Africa, the system transformation aimed at through digitalization was always challenge-oriented, or even mission-oriented, and this from very early on. Hence, we cannot observe that challenge-oriented or, if you will, transformative innovation policies have been adopted only recently as suggested in the literature. This finding may have to do with the fact that in this study, we did not select the traditional innovation policy instruments that policy makers usually have at their disposal but rather took a system perspective, which considers policies from different domains relevant to the system transformation. It could be interesting to investigate broader policy themes such as digitalization in a Global North context and investigate whether a broader consideration of policy domains would lead to similar findings. This would then imply that there could be plenty of historical examples in different contexts to learn about "whole of government" approaches, which are foregrounded as novel in the transformative innovation policy literature.

In the case of both South Africa and Rwanda, despite their contextual differences, we could observe similarities in how the digital transformation was governed. At the beginning, in both cases, there was a strong emphasis on system building, which included physical infrastructure (e.g., networks), institutional infrastructure (e.g., regulatory bodies), and capabilities (e.g., skills). This also included a strong emphasis on technology-push with investments, for instance in, research and development. Following these system building efforts, policies focused on developing digital services, products, and production processes, which would be at the core of the digital transformation of the economy and society. In the last phase, policy turned more towards regulating the digital transformation to address potential risks and unintended consequences of digitalization, for instance, related to cybersecurity.

Another common feature of governing the digital transformation in both countries was a process of increasing specificity and specialization of policies. At the beginning, in the 1990s and early 2000s the policy documents in both countries provided a rather broad framing of digitalization. There was the idea about the transformative potential of digitalization but there was still limited knowledge about how this transformation would unfold. With time, the policies have become increasingly more specific and detailed regulating particular themes such as skills, entrepreneurship, industry 4.0, and cybersecurity.

What is the general relevance of these findings? The importance of system building for system transformation, this is to say for the society and economy to be able to take up a particular transformation such as digitalization or renewable energies, may be a general point. Without basic infrastructure, knowledge, regulations, and skills, a system transformation may be impossible to achieve. Furthermore, that the development and uptake of new products, processes, services, business models generate momentum in the backwater of system building appears also a generic feature as is that the consequences of the transformation will become known as result of the increasing uptake of the innovations. What could potentially differ is that certain transformations require more of the technology-push than others. Digitalization without technological change is not thinkable. Technology-push is also important in other transformations, for instance, in the field of hydrogen or batteries for the green energy transition. However, the investigated policies made no sufficient provision for aspects related to the change of behavior and social practices even though it became evident that digitalization and social contexts shape each other.

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Appendix

A 1. Digital development policies in Rwanda and South Africa

Country	Policy	Year	Principal Entity
Rwanda	An Integrated ICT-led Socio-Economic Development Policy and Plan for Rwanda NICI I (NICI-2005)	2001	Government of Rwanda (GoR)
	An Integrated ICT-led Socio-Economic Development Plan for Rwanda NICI II (NICI-2010)	2005	GoR
	National ICT Strategy and Plan NICI III (NICI-2015)	2010	GoR
	National Broadband Policy for Rwanda	2013	GoR
	Smart Rwanda 2020 Master Plan	2015	Ministry of Youth and ICT (MINICT)
	National Cyber Security Policy	2015	GoR
	National Digital Talent Policy	2016	MINICT
	ICT In Education Policy	2016	Ministry of Education (MINEDU)
	National Data Revolution Policy	2017	MINICT
	ICT Sector Strategic Plan 2018-2024	2017	MINICT
	Law Establishing the National Cybersecurity Authority and Its Mission, Organization and Functioning	2017	GoR
	Law Establishing Rwanda Information Society Authority And Determining Its Mission, Organization and Functioning	2017	GoR
	ICT Hub Strategy 2024	2018	Ministry of ICT &Innovation (MINICT)
	Local Digital Content Promotion Strategy and Implementation Plan 2018-2022	2018	MINICT
	Guideline on Minimum Bandwith Broadbrand Internet Connectivity in Rwanda	2018	Rwanda Utilities Regulatory Authority (RURA)
	Prevention and Punishment of Cyber Crimes	2018	GoR
	ICT for Governance Cluster Strategy 2020-2024	2019	GoR
	Data Centre and Cloud Services Directives	2019	Rwanda Information Society Authority (RISA)
	Rwanda Child Online Protection Policy	2019	MINICT
	Cyber Security Regulation	2020	RURA
	Rwanda Digital Acceleration Project	2021	MINICT/RISA
	The National Broadband Policy and Strategy	2022	MINICT
	Rwanda Fintech Policy 2022–2027	2022	MINICT, MINECONFIN (Ministry of Finance and Economic Planning)
South Africa	Telecommunication Act	1996	Government of South Africa (The Republic)
	State Information Technology Agency Amendment Act No 88 of 1998	1998, amended 2002	The Republic
	Independent Communications Authority of South Africa Act, No. 13 of 2000	2000	The Republic
	Electronic Communications and Transactions Act 2002	2002	The Republic
	Electronic Communications Act, 2005: No. 36 of 2005	2005	The Republic
	Broadband Infraco Act No 33 of 2007	2007	The Republic
	Broadband Policy for South Africa	2010	Department of Communications (DoC)
	Broad-Based Black Business Economic Empowerment (B-BBEE) ICT Sector Code	2012	Department of Trade and Industry (DTI)
	South Africa Connect: South Africa's Broadband Policy	2013	DoC
	National Integrated ICT Policy White Paper	2016	Department of Telecommunications and Postal Services (DTPS)
	National e-Strategy Digital Society South Africa	2017	DTPS
	National e-Government Strategy and Roadmap	2017	DTPS
	ICT SMME Development Strategy	2017	DTPS
	National Digital and Future Skill Strategy South Africa 2021-2025	2020	Department of Communications and Digital Technologies
	Cybercrimes Act 2021	2021	The Republic

A 2. Approach to calibrating the goals and rationales in digital development policies

Goal	Economic growth & competitiveness				Even & just development (between groups and places)				Environmental & ecosystem protection			
Calibration/Scale	1	0.67	0.33	0	1	0.67	0.33	0	1	0.67	0.33	0
Description	Explicitly expressed policy outcome/ desired impact	Mentioned as policy outcome/ desired impact	Mentioned as byproduct of the policy's outcome	Policy outcome absent	Explicitly expressed policy outcome/ desired impact	Mentioned as policy outcome/ desired impact	Mentioned as byproduct of the policy's outcome	Policy outcome absent	Explicitly expressed policy outcome/ desired impact	Mentioned as policy outcome/ desired impact	Mentioned as byproduct of the policy's outcome	Policy outcome absent

Rationale	Technology-push, linear innovation policy rationale				Systemic innovation policy rationale				Transformative/system change innovation policy rationale			
Calibration/Scale	1	0.67	.33	0	1	0.67	.33	0	1	0.67	0.33	0
Description	Explicit focus on science & technology promoting R&D and inventions	Science & technology clearly part of policy but rationale not fully articulated	Science & technology not prime purpose of the policy but some elements are included	Science & technology not addressed	Explicit focus on system building strengthening capabilities, networks, institutions or infrastructure	System building clearly part of policy but rationale not fully articulated	System building not prime purpose of the policy but some elements are included	System building not addressed	Explicit focus on system change intervening in patterns of consumption, distribution, & production	System change clearly part of policy but rationale not fully articulated	System change not prime purpose but some elements are included	System change not addressed

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