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An Evolutionary Analysis of Transformative Change in LDCs: the cases of Kenya and Rwanda

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Abstract

This paper draws on insights from evolutionary economics to enrich our understanding of the prospects for development in low-income countries. Drawing on analysis Freeman and Perez (1988) of the basis for changes in technological economic paradigms, the paper argues that the current process of digitalization in combination with developments in renewable energy are providing a 'window of opportunity' for accelerated economic growth and catch-up in low-income countries. The argument is illustrated with reference to the cases of Kenya and Rwanda both which stand out for their governments' foresight in pursuing policies designed to promote a transformation based on the opportunities offered by the revolutionary changes in technology from the early to mid-2000s. Transformative change requires innovations in business models, in products and process and in modes of marketing and distribution. Drawing on innovation systems theory, the paper considers to what extent the problems firms face in Kenya and Rwanda in accessing resources in terms of needed knowledge, skills and finance have constrained the development of their innovation capabilities. The paper concludes by assessing the policies governments have enacted in attempting to respond to these constraints.

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1. Introduction

What mainly distinguishes evolutionary economics from other approaches to the study of economic phenomena is its emphasis on qualitative changes in historical time, and factors influencing such processes. Since qualitative changes in production, consumption, organizational forms, institutions, etc. arguably is what economic development is about, one would expect an approach focussing on such changes to be very relevant for the study of what policymakers in low-income countries can do to upgrade economic structures and increase the welfare of the population. Nevertheless, evolutionary economists from Joseph Schumpeter onwards have mainly focused on the leading capitalist countries and other highly mature economies. The small set of (mostly Asian) countries that during the last half-century managed to substantially reduce the gap in productivity and income vis a vis the developed part of the world has also received attention. However, very little systematic work has been undertaken on the economics of lower-income countries from an evolutionary perspective. This paper aims to address this gap by explicitly focusing on the extent to which insights from evolutionary economics may enrich our understanding of the prospects for lower-income countries in Africa. As a prelude, section 2 below discusses some central insights from the evolutionary economics literature that potentially may be of high relevance for the task. The outcome of this exercise is put to the test in sections 3 and 4 based on evidence from two low-income African countries, Kenya and Rwanda, with section 3 focusing on the impact of recent technological changes, and section 4 on the role of policy in promoting these changes. Section 5 concludes.

2. Economic development in low-income countries: An evolutionary perspective

If the hallmark of neoclassical economics is equilibrium (and how to achieve and sustain it), evolutionary economics is about qualitative, innovation-driven change. It was Joseph Schumpeter who more than a century ago started to analyze economic development in this way (Fagerberg 2003). From this perspective, the key social phenomenon that needs to be understood is innovation, defined as the introduction of novelty in the economic sphere (rather than, say, as new ideas or "invention").[1]

While it is common to associate innovation with outstanding scientific breakthroughs and/or high-tech environments, Schumpeter – and evolutionary economics – places innovation in a much broader context. According to Schumpeter, innovations come in many different

[1] As Schumpeter famously pointed out: "As long as they are not carried out into practice, inventions are economically irrelevant. And to carry any improvement into effect is a task entirely different from the inventing of it, and a task, moreover, requiring entirely different kinds of aptitudes." (Schumpeter 1934, p. 88).

shapes, e.g., not only technological but also organizational, and different sizes, ranging from very radical innovations to minor changes in existing products and processes, and they all matter. Moreover, innovation is not something that only goes on in select high-tech environments or the manufacturing industry. Innovation, from an evolutionary perspective, is something that goes on – and matters – in all kinds of economic activities, i.e., in services and industry, as well as in the public and private sectors (Fagerberg 2004). Although much innovation occurs in private businesses and with a profit motive, innovations may also occur in other settings and be driven by other motivations, e.g., so-called social innovations (Moulaert et al. 2013). Furthermore, novelty may be regarded as context-dependent, i.e., introducing something for the first time in a new context may also qualify as an innovation, even if it is not necessarily "new to the world" (Smith 2004). Thus, evolutionary economics sees innovation as a potent force for change in a broad range of sectors and activities, in developed as well as developing countries.

This being said, Schumpeter and many evolutionary economists with him have an especially keen interest in radical innovations, particularly those having a major influence on the behaviour of the entire global economy over an extended period of time, what Freeman and Perez (1988) call "technological revolutions" or "changes in techno-economic paradigms". The defining feature, they argue, is the existence of a cheap key input characterized by rapidly declining costs, almost unlimited supply, and very broad applicability (ibid, p, 48). This may lead to a virtuous circle, in which both the industry producing the key input and industries using it extensively (the "carrier" branches) grow very fast, resulting in rapid productivity growth and extensive structural changes in the economy. As examples of such key inputs, Freeman and Perez (1988) identified energy (especially oil) from the 1930s to the 1980s, and microelectronics from the 1980s onwards. More recently, it has been argued that the rapid progress in renewable energy technologies, particularly solar and wind, also qualify as a technological revolution and can be expected to have a similarly broad impact all over the globe (Mathews 2013, 2014). A similar point has been made regarding the potentially transformative effects of the so-called digital revolution of the last 10 to 15 years, driven by mobile telephony and rising internet usage (Zysman and Kenney, 2016; Africa's Pulse, 2019).

As Freeman and Perez (1988) emphasize, technological revolutions have implications far beyond technical change, involving large infrastructural investments with pervasive effects throughout the economy, including changes in managerial and organization practices and new patterns of distribution and consumption of goods and services. In drawing inspiration from this framework to analyze development processes in lower-income countries, a first point to consider is to what extent the recent technological changes display sufficiently infrastructural novelty relative to the existing paradigm to offer a 'window of opportunity' for catching-up. At the level of ICTs, the key new technological development of the 2000s is often referred to as a process of 'digitalization' depending on the increasing use of the internet and electronic devices to generate, process and exchange data. While digitalization

builds on the microelectronics revolution of the 1980s and 1990s, it displays several new elements that may allow developing countries to forego some of the telecommunications infrastructural investments made by developed countries, and to establish new patterns of consumption of goods and services linked to new types of distribution and consumer behavior. These include notably: 1) the development of wireless mobile telephone communication networks as an alternative to investment in fixed landline communication systems; 2) the development of digital service platforms that can be easily accessed over the Internet with mobile phone-based applications, thus providing increased and more inclusive access to a range of new services in such areas as finance, logistics, health care, and agriculture; and 3) the increasing use of the Internet and social media not only as a means of transmitting information but also for cooperation and knowledge exchange supporting product and process innovation.[2] A key input to digitalization trends, characterized by rapidly declining costs, is wireless broadband connectivity, which has experienced a dramatic fall in prices over the last decade.[3]

With respect to renewable energy, this is an unfolding technology that promises to progressively replace carbon-based energy supply in all countries to varying degrees. This has been encouraged by the declining cost of renewables, which is now at parity or even below that of energy supplied by oil, coal and gas-powered plants.[4] In low-income countries in Africa, the large shares of the population, especially in rural areas, that lack access to electricity through the national grid are increasingly in a position to benefit from small scale and decentralized renewable energy installations, including standalone off-grid solar and min-grid solar, wind or hybrid systems. Digitalization may support the adoption of renewable energy in two ways. First, digital technologies can transform value chain relations supporting both finance, installation and maintenance of standalone off-grid solar, thus contributing to electricity provision on a decentralized basis.[5] At a somewhat larger scale of operations, digital technologies and analytics can be applied to mini-grids being powered by intermittent renewable resources to balance electricity demand and supply and to ensure an efficient system operation (Fritzsche et al. 2019). Hence, the interaction between the renewable energy revolution and the digital revolution may offer great opportunities for developing countries – see the discussion in sections 3-4 of this paper.

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[2] For a recent survey of the literature, see Bhimani, et al. (2019).

[3] World Bank reports (2019 and 2020) estimate that following the landing of several undersea cables on the African continent access to international bandwidth capacity grew more than threefold in Kenya between 2015 and 2018 and tenfold in Rwanda between 2015 and 2020.

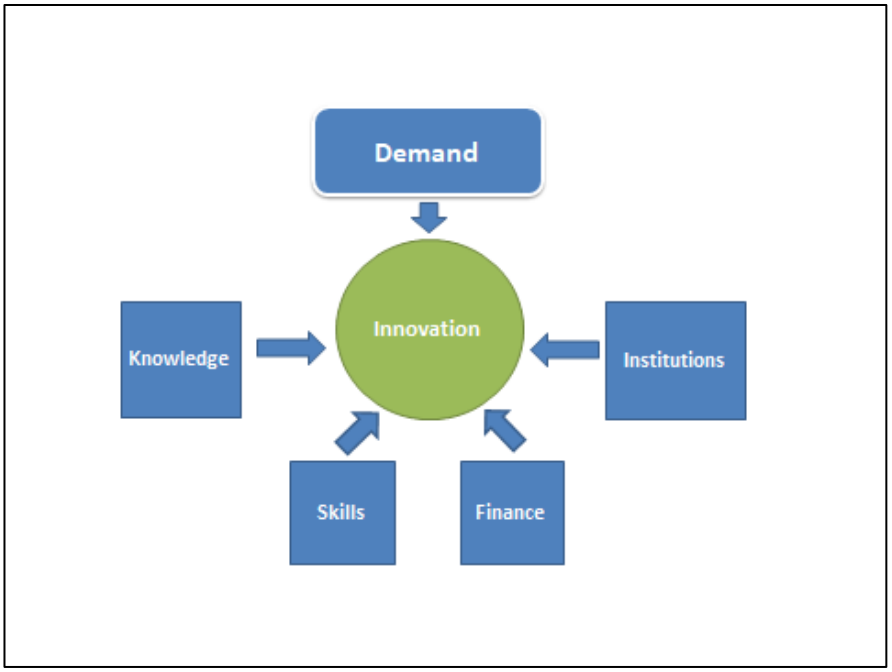
[4] According to a recent Forbes report, the average cost of developing new power plants based on onshore wind, solar photovoltaic (PV), biomass or geothermal energy is now usually below $0.10/kWh and so is able to compete with the cost of developing new power plants based on fossil fuels such as oil and gas, which typically range from $0.05/kWh to over $0.15/kWh. https://www.forbes.com/sites/dominicdudley/2019/05/29/renewable-energy-costs-tumble/

[5] See the discussion below of M-KOPA Solar in Kenya and the equivalent pay-as-you-go solar home systems in Rwanda.

Another major difference between evolutionary and neoclassical economics concerns the capabilities of the actors that take part in the economic process. While neoclassical economics traditionally depict actors as "rational" and endowed with perfect information on all issues of relevance for economic decision-making, evolutionary economists see actors as being much more constrained in this regard, particularly in their attempts to identify and access relevant knowledge and exploit it in innovation (Nelson and Winter 1982). The latter, more realistic view, has found a great following, especially in business and management studies (Fagerberg et al. 2012). In fact, developing the ability to identify, access and exploit relevant knowledge – so-called "absorptive capacity" (Cohen and Levinthal 1990) or "technological capability" (Kim 1997) – is widely recognized as a major challenge for firms. Arguably, this problem may be even more pressing for developing country firms, being far from the technological frontier and major knowledge hubs, and policies improving the absorptive capacity and technological capability of domestic innovation actors, therefore, deserve a high place on the policy agenda in the developing part of the world (Fagerberg et al. 2010).

Schumpeter used the metaphor "new combinations" to characterize innovation. Hence, what is novel is not necessarily the constituent parts but the way they are put together. In this combinatory dynamics, innovative firms draw on various resources such as knowledge, skills and finance (Figure 1), and the possibility to succeed may critically depend on their ability to mobilize these resources (Fagerberg 2004). Innovative firms also depend on whether there is a market for their innovations: Innovations that are not sufficiently appreciated by potential customers or selected against, are doomed to failure. The institutional framework – laws, regulations, practices - into which they are embedded also matters.

Figure 1. Innovation



Moreover, these various factors are often complementary rather than substitutes. For example, it is of little help to have access to some potentially interesting knowledge, if you lack the skills to exploit it, the required financial backing for doing so, or if demand is lacking. There are important lessons from this, not only for firms (that tend to learn this the hard way) but also for policymakers that wish to encourage innovation. That is, to succeed with innovation support, it is not sufficient to focus on one particular resource, say knowledge, because there may be other constraints that are equally or more relevant (Bergek et al. 2008). Thus, effective innovation policies cannot be based just on abstract principles but require detailed knowledge of the working of the innovation system, being local, regional or national (Edquist 2004), that policymakers wish to influence. This raises the bar for policymakers, not the least in lower-income countries where, in most cases, governance is weak and appropriate knowledge infrastructures are poorly developed.

Innovation is increasingly acknowledged – not only by evolutionary economists but more broadly – as a key factor in economic development as well as a tool for dealing with more specific challenges that policymakers are facing (giving rise to so-called mission-oriented innovation policies, see, e.g., Mazzucato 2013). It is not surprising, therefore, that the attention to the role of governance and policy in encouraging and influencing innovation has been on the rise during the last few decades (Fagerberg 2017). However, the great uncertainty in innovation, as well as the widely distributed nature of relevant knowledge, has generally led evolutionary economists to emphasize policies that strengthen the national system's capacity for innovation in all sectors or industries, such as supporting capability-building, financial access, and interaction between different actors (e.g., public and private)

in the innovation system, rather than devising more specific paths for how the future should look like (and hence where innovation would be most needed). Nevertheless, the global climate challenge (Stern 2015) and the political reactions to it (e.g., the UN's Paris convention from 2015) has arguably provided a clearer direction for society's development in the years to come, e.g., a transition from an energy system based on burning fossil fuels to renewable energy, combined with huge savings in energy and resource use (circular economy). An important question, therefore, which has attracted much attention recently, is how innovation – and policies supporting it – can contribute to these changes.

Among the requirements mentioned in the literature[6] is, first, a clearer direction for policy – guided by a vision for a country's or region's future development, based on the opportunities offered by the revolutionary changes in technology as well as more specific features of particular relevance for the country or region in question. Since the transition to sustainability will take several decades, the vision (direction) guiding change needs to be durable, e.g., resilient to the electoral cycle (Fagerberg and Hutchenreiter 2020). Thus, to be effective in its aims, such a vision requires broad support in society. Second, the transition requires numerous changes in all parts of society, that support - rather than contradict - each other. This points to a veritable coordination problem that needs to be addressed if the transition is going to be successful. A common vision guiding the process – working towards a common goal - may be helpful in this regard. However, better coordination between different parts of government (whose activities matter for innovation) and greater involvement of other stakeholders in society will also be required. While undoubtedly very challenging for the already developed part of the world, deeply embedded as they are in the old fossil-fuel based industrial system, developing countries may possibly turn this situation to their advantage, by – as pointed out above - embracing the opportunities offered by the more recent technological developments in areas such as e.g., renewable energy and telecommunications.

3. Windows of opportunity for transformative change in Africa

Achieving Africa's ambitious vision towards a sustainable and inclusive future (as set by the African Union's pan African strategy, 'Agenda 2063: The Africa We Want') requires profound transformations of production, consumption and governance systems. Transforming Africa into "a global powerhouse of the future", as this strategy envisions, requires not only catch up through imitation but widespread innovation, with new products, new services, new processes and new businesses emerging, that result in sustainable outcomes. Already, off-grid renewables are enabling "unscaling" of the energy system, challenging the monopoly power of national utilities through the emergence in Africa of 'prosumers', i.e., people who

[6] See e.g., Steward 2012, Weber and Rohracher 2012, Schot and Steinmueller 2018, Fagerberg 2018, EEA 2019.

are both producers and consumers of power. The use of mobile money has grown exponentially in Africa over the past ten years, making the region the global leader in mobile money innovation and adoption, thus paving the way to develop indigenous digital service platforms transforming patterns of production and consumption.

These transformations may not be merely avenues to "catch-up", following the path of already mature economies. One may also see them as opportunities for "path-breaking", as an essential strategy in the context of climate change and the urgent need to reverse the unequal patterns of distribution from earlier development paths. But transformation is a long-term process, not automatic, and depends on the strength of the national innovation system, shaped by the interactions and learning among various organizations and institutions under the influence of government policies. It also depends on having the foresight and political will to put in place these policies. In this regard, the commitment to accelerate the continent's transformation by harnessing its vast renewable energy potential and digital technologies is reflected in current strategies such as the Africa Renewable Energy Initiative (2015)[7], and the Digital Transformation Strategy for Africa (2020)[8].

Below we focus on recent developments in Kenya and Rwanda. Both countries stand out for their foresight in pursuing policies designed to promote a digital transformation based on mobile telephony and the Internet from the early 2000s. More recently, both Kenya and Rwanda have emphasized the adoption of off-grid solar and wind as solutions to the challenge of providing electricity to the parts of their rural population located far from the national grid. The focus on Kenya and Rwanda is also guided in part by the fact that they consistently have been among the top 10 fastest growing countries in Africa since 2000 (World Bank Data). [9]

Digital and energy transformation in Kenya and Rwanda

Key components of the digital transformation underway in Kenya and Rwanda from the mid to late 2000s are (a) the rapid development of wireless mobile telephone communication networks as an alternative to costly investments in fixed landline communication systems and (b) the development of digital service platforms that can be accessed over the Internet with mobile phone-based applications and that are providing increased and more inclusive access to a range of new services in such areas as finance, logistics, health care, and agriculture (World Bank Group, 2019 and 2020).

[7] See: http://www.arei.org/

[8] See: https://au.int/en/documents/20200518/digital-transformation-strategy-africa-2020-2030

[9] Rwanda's economy grew at an average 7.7% between 2000-2019, and GDP growth in Kenya, averaged 5.3% from its economic recovery in 2004 until 2019. See, World Bank development indicators: data.worldbank.org/

In presenting empirical support for this, a first point to emphasize is the transformative impact of these technological developments. As with most countries in Sub Saharan Africa (SSA), neither Kenya nor Rwanda benefited significantly from the ICT revolution taking hold in developed countries from the 1980s and 1990s characterized by the wide adoption of computers and increased use of the Internet. This was closely connected to the lack of investments in their fixed landline telecommunication systems since at this time, an internet connection required a computer and the use of a modem to dial up a connection. Table 1 shows that in 2000 the number of fixed-line connections per 100 persons was under 1% in both Kenya and Rwanda compared with an average of about 54% in high-income countries.

Table 1
Number of Fixed Line Telephone Subscriptions per 100 Persons

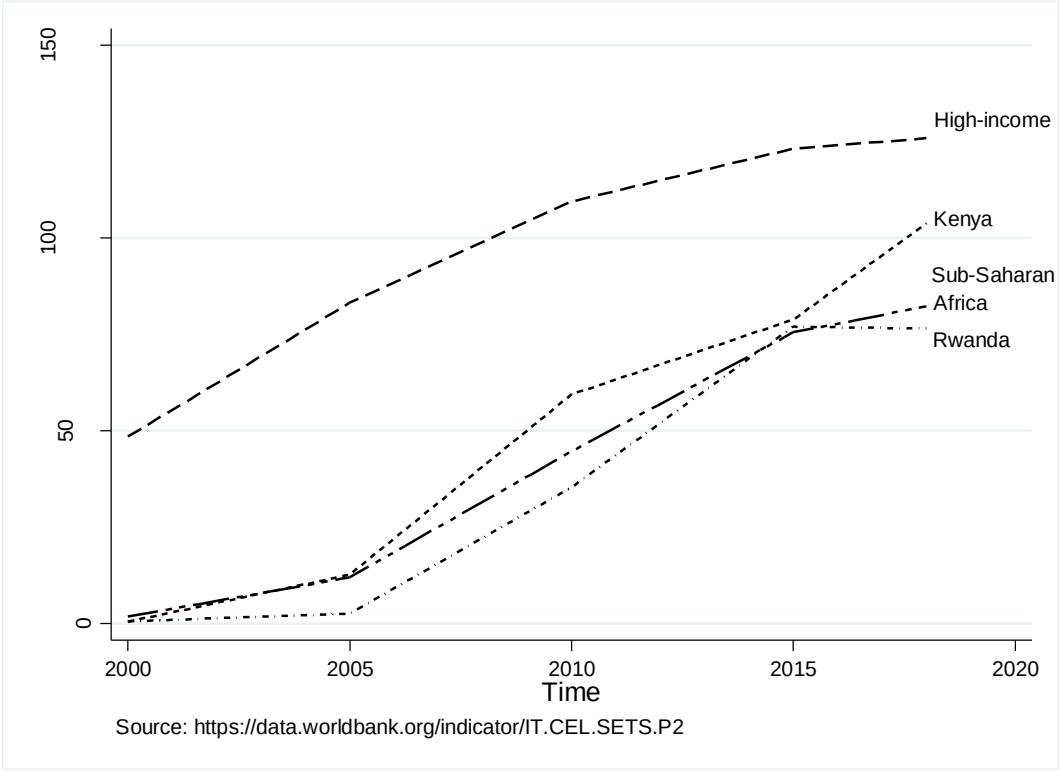
Year	Kenya	Rwanda	SSA	High-Income
1990	0.74	0.14	0.99	40.53
2000	0.92	0.22	1.38	53.90
2010	0.91	0.39	1.48	46.93
2018	0.13	0.11	0.81	38.80

Source: World Bank Data: https://data.worldbank.org/indicator/IT.MLT.MAIN.P2

The number of fixed-line subscriptions in high-income countries declined after 2000 and was quickly surpassed by mobile subscriptions. The radical transformation in telecommunications access in Kenya and Rwanda brought about by the diffusion of mobile phones can be seen in Figure 2 below. Mobile telephone subscriptions increased rapidly after 2005, substantially closing the gap with high-income countries by 2019. This diffusion improved internet access supported by the dramatic decline in broadband cost after 2009 with the arrival of several submarine cables connecting the African continent to global internet services. In 2019 over 48% of Kenya's population had access to broadband connectivity, predominately through the mobile phone network (World Bank Group 2019). In Rwanda, access to international bandwidth increased 10-fold between 2015 and 2020, giving Rwanda the highest 4G coverage of any Eastern African country, standing officially at over 95% of the population (World Bank Group, 2020).

Figure 2

Number of cellular mobile subscriptions per 100 persons



Source: https://data.worldbank.org/indicator/IT.CEL.SETS.P2

These technological and infrastructural developments, as pointed out above, can only be expected to have a transformative effect on the economy if they are accompanied by innovations in business models and patterns of production and consumption. In Kenya and Rwanda, this manifested in the development of indigenous digital platforms providing access to a range of new services, including finance, health, and agricultural supply chain management. Kenya is thought to have experienced the fastest growth in the number of digital platforms in SSA (estimated at 118 platforms in 2019), primarily indigenous or homegrown (80% of them) (Insight2impact, 2019).

The most widely discussed case is undoubtedly Safaricom's mobile money platform, M-Pesa, which experienced explosive growth from 2 million registered users within a year of its start in 2007 to over 10 million by the end of 2010 (Demirguc-Kunt et al. 2015), and over 40 million worldwide in 2020. The use of mobile money expanded from making remittances to include individual payments for goods and services and business transactions, including payments for inputs, paying employees, and receiving customer payments (Gosavi, 2015; Lorenz and Pommet, 2020). Further, the platform spawns a range of innovative digital services based on the Pay-As-You-Go business model allowing customers to use their mobile money accounts

to finance their purchase of assets over time, including solar home systems (SHS) and solar-powered televisions (Adwek et al. 2020).

The uptake of mobile money in Rwanda, while significant, has been less rapid than in Kenya; with 31% of Rwandan adults having a mobile money account in 2017, up from 18% in 2014. As in the case of Kenya, remittances have been a significant use of mobile money with approximately 33% of the adult population sending or receiving remittances in 2017, and of these about 73% using mobile money to make the transaction.[10] In Rwanda, the development of digital platforms has to a greater extent than in Kenya, been driven by public investments. The Rwandan government has pursued an ambitious e-government strategy expanding its e-services from only five in 2015 to some 89 in 2018 (World Bank Group, 2020).

The transformative impact of new digital technologies is paralleled by renewable energy's potential to transform economic activity, especially in rural areas, by providing cheap and decentralized energy supply. The share of the rural population with access to electricity increased in Kenya from about 30% in 2011 to 72% in 2018, thanks to a combination of grid extensions and investments in off-grid capacity. In Rwanda progress was slower (23% of the rural population had access in 2018).[11] While solar energy constitutes a small share of power generation capacity in both countries, solar in the form of off-grid mini and solar home systems plays an important role in rural electrification and, as shown in Figure 3 below, accounts for most of the recent increase in off-grid capacity (Moner-Girona, 2019). The uptake of off-grid solar has been driven by the steep decline in the cost of solar photovoltaics, estimated at 82% between 2010 and 2019, more than any other electricity generation technology (IRENA, 2020b). The adoption of solar home systems (SHS) and solar lamps has largely depended on digital platform-based start-ups that offer individual households solar energy systems that are paid for with mobile money using pay-as-you-go financing.

In Kenya, M-Kopa is the most important provider of off-grid solar home systems, having wired by 2018 over 600,000 homes in East Africa.[12] Most of the rural population serviced by M-Kopa depends on agriculture, and there is an emerging market for solar-powered appliances in agriculture and downstream agro-processing, including solar pumps and solar-powered milling and pressing equipment. As in the case of solar home systems, this equipment may be financed with pay-as-you-go systems using the M-Pesa mobile money platform (Africa's Pulse, 2019).

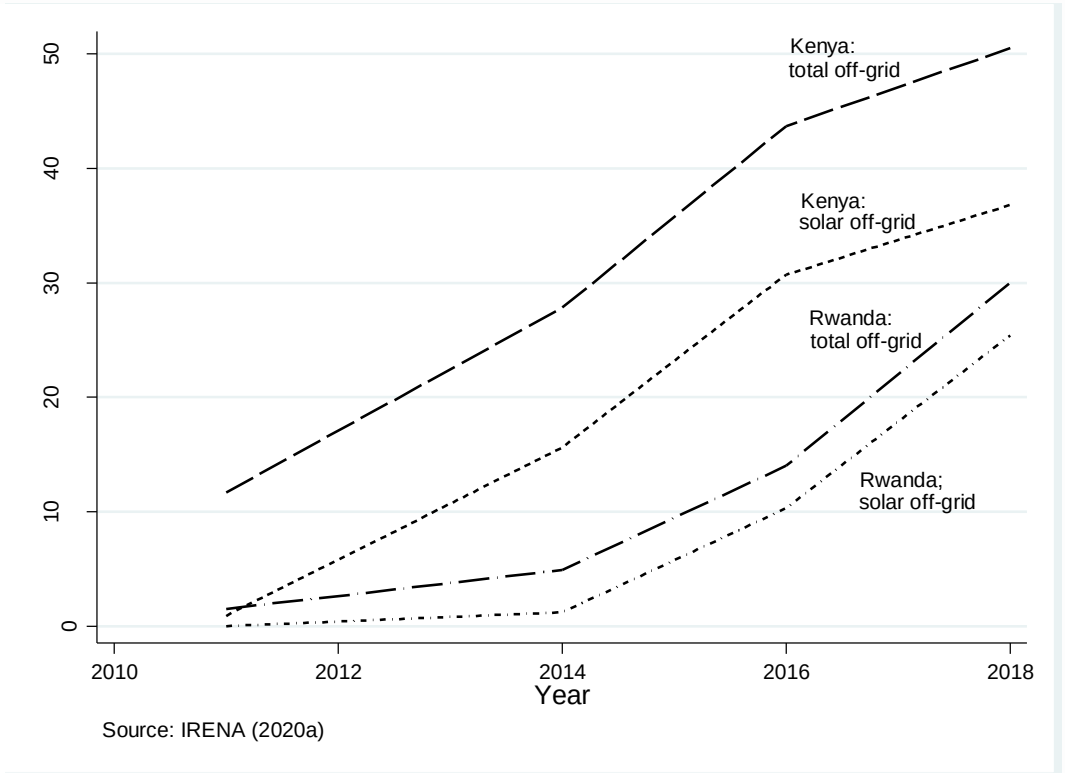
[10] See: Global Findex Database, 2017: https://globalfindex.worldbank.org/

[11] See: World Bank Development Indicators: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS).

[12] See: http://www.m-kopa.com/.

Figure 3

Off-grid energy capacity in Kenya and Rwanda in Megawatts



Source: IRENA (2020a)

In Rwanda, linkages between digital platforms and off-grid solar are emerging. In 2018 approximately 11% of the population was connected to off-grid systems, primarily solar-based. Several independent companies have wired up to 300,000 households with solar home systems and in some cases offer pay-as-you-go finance through mobile phone platforms (Republic of Rwanda, 2017b).[13] As in Kenya, there is an emerging market for solar-powered agricultural equipment (possibly financed through pay-as-you-go financing systems).[14]

These developments in standalone off-grid solar home systems and other solar-powered products hint at the transformative potential of solar energy. They indicate that solar is more than an infrastructure for energy generation and supply. Solar energy, facilitated by digital

[13] For the activities of the enterprise Ignite Power in Rwanda, see https://www.esi-africa.com/news/off-grid-power-illuminates-rwandan-villages/

[14] See, for example, https://futurepump.com/futurepump-rwanda/

mobile finance platforms, demonstrates its transformative potential by being incorporated in many products in several sectors.

4. Policies for transformative change

A profound transformation is required for Africa to achieve its vision while responding to the urgent threats posed by climate change and the social consequences of the unequal distribution of wealth and opportunities. Arguably, a poorly managed transformation is unlikely to result in the realization of the "path-breaking" potential brought by renewable energies and new digital technologies. The literature on transformative change points out that the process of change is uncertain, since it involves interdependent adjustments in technologies, business models, behaviours with possibly unanticipated consequences (EEA 2019). While there is no simple rule for what policies should be adopted to promote transformative change, as we noted above the literature points to the importance of having a clear direction for policy based on a longer-term vision for the country's development, and of the alignment of polices across different domains and parts of government.

Transformative change also hinges on the involvement of multiple stakeholders, including not only government and private sector businesses, but also NGOs, international partners and civil society more widely. Governments also need to be attentive to making investments in appropriate infrastructure and to enacting measures to ensure that innovative firms can mobilize the necessary resources in terms of knowledge, skills and finance to roll-out their innovations and connect them to potential markets (Comins and Kraemer-Mbula, 2016). As we pointed out above (see Figure 1), these various resources are interdependent and complementary in nature. This implies that effective policymaking requires identification of which, if any, are binding constraints and are in need of intervention (and the selection and implementation of relevant instruments) so the opportunities entailed by digitalization/renewables are realized. Below we consider for the cases of Kenya and Rwanda how government policies have responded to these challenges of supporting transformative change through regulation, infrastructural investment and policies to support skills development access to finance and entrepreneurship.

Vision and governance for transformative change

A first point to emphasize is that in both Kenya and Rwanda, government policies have been guided since the early to mid-2000s by long-term visions for achieving higher growth with greater inclusiveness. Moreover, in each country, political reforms have been enacted with the aim of increasing the degree of coordination and alignment between different policy domains. Rwanda's Vision 2020 that was established in 2000 aimed to transform Rwanda from an agrarian to a knowledge-based society with universal access to education and

healthcare and the promotion of private-sector-led development as pillars. Successive five-year ICT-led Socio-Economic Development Plans explicitly gave a cross-cutting role to ICTs in achieving the goal of transforming Rwanda into a knowledge-based society (Government of Rwanda, 2000, 2005, 2010). These 5-year plans, which envisaged that Rwanda would become an ICT hub for western Africa, were closely aligned with successive Economic Development and Poverty Reduction Strategies (EDPRS) that started in 2008 and set out medium-term objectives to improve access to education and skills development and to develop sectors with a strong environmental and natural resource content (e.g. water supply and sanitation), identified as essential to achieving healthcare goals (Republic of Rwanda, 2008 and 2013). These EDPRS were aligned with energy policies that gave emphasis to increasing the share of renewables in the energy mix including micro wind, solar and possibly geothermal (Republic of Kenya, 2015).

Kenya's Vision 2030 was established in 2008 and envisaged transforming Kenya into a globally competitive and prosperous economy and society, simultaneously pursuing social inclusiveness. From 2008 a series of medium-term plans identified as key pillars the development of energy and ICT infrastructure, and science, technology and innovation capabilities (Republic of Kenya, 2008). It was explicitly recognized that Kenya's Vision 2030 implies an increased energy demand in the form of electricity and the Renewable Energy for All Action Plan called for a doubling of share of renewables in the overall energy mix (Republic of Kenya, 2015). The 2013 Science, Technology and Innovation (STI) Act contributed to increasing the level coordination and coherence of STI policies in Kenya (Ayisi, et al. 2019) and to responding to what were perceived at the time to be key weaknesses with the Kenyan NIS due to the entities in charge of STI policymaking operating in isolation and having weak links to academic institutions and the private sector (Kenyan Ministry of Education, 2015). The 2013 Act established under the control of the Ministry of Education a new governance structure for the coordination and regulation of science, technology and innovation policies based on three new institutions. These were the National Commission for Science, Technology and Innovation (NACOSTI), with a mandate for setting STI priorities in consultation with stakeholders and ensuring coordination between the various agencies involved in science, technology and innovation; the Kenya National Innovation Agency (KENIA) with a mandate for managing the Kenyan NIS in part by institutionalizing linkages between universities, research institutions, the private sector, the government, and other actors; and the National Research Fund (NRF), aligned with NACOSTTI and KENIA and designed to provide funding for research and innovation projects (Kenyan Ministry of Education, 2015). The fact that these institutions are under the responsibility of the Ministry of Education facilitated alignment with skills development policies as discussed below.

Infrastructural investments for digital communications and renewable energies

To encourage private sector investments in the ICT sector, the Kenyan and Rwandan governments moved early on to liberalize their telecommunications sectors. However, in practice, the monopoly over internet access exercised by the state-owned providers only came to an end in 2006 in Rwanda, and in Kenya in 2007 (Mureithi, 2017; Government of Rwanda, 2005). In Kenya, a key development contributing in a largely unanticipated manner to the subsequent growth of the digital economy was the Central Bank's decision in 2007 to issue Safaricom a letter of no objection authorizing it to launch M-Pesa. This enabled the regulatory environment for the subsequent explosive growth of mobile money referred to above.

Digital infrastructure and connectivity improved substantially after 2008-09 in both countries following the landing of several international submarine cables as described in Section 3 above. This was complemented by government investments in domestic fiber-optic infrastructures to connect different regions and cities. In Kenya, there have been substantial private sector infrastructural investments by the main mobile network operators (Orange Telkom, Safaricom, Airtel and Essar), which have developed their own ICT infrastructures (Kenya Master ICT Plan, 2014, p. 31). In Rwanda, public investments made in the national and metropolitan fiber networks are open to private enterprises in an attempt to promote private sector investment (Republic of Rwanda, 2017a).

A central objective of energy policy in both countries has been to reduce dependence on biomass for cooking and heating, which presents severe health and environmental risks. Rwanda's Vision 2020, for example, called for substantial reduction in the use of firewood by 2020 while Kenya's Vision 2030 laid more emphasis on increasing the use of non-solid clean fuels (Republic of Kenya, 2018). Policies in Kenya to increase access to electricity through renewable wind or solar focused mainly on national grid extensions until 2016-17, when greater emphasis was given to solar off-grid with an NGO supported program for the installation of solar PV systems in primary and secondary schools as well as health and administrative centers.[15] Off-grid solar was given a boost by the creation of the Rural Electrification and Renewable Energy Corporation (REREC) in 2019 with a mandate to put renewable energy, including mini-grids, standalone solar systems, and solar water pumps for community facilities, at the center of policy.[16]

In Rwanda, as early as 2013, off-grid renewables were attributed a central role in increasing electricity supply and in particular, for assuring 100% provision of electricity to schools, health centers and public offices by 2017. Private sector investments were encouraged with

[15] See: https://energy4impact.org/news/improving-health-and-education-services-marginalised-rural-communities-kenya

[16] See: https://www.rerec.co.ke/ for the off-grid programs of the Rural Electrification and Renewable Energy Corporation

the Ministry of Infrastructure mandated to provide transaction support and coordination among the stakeholders, including through the establishment of PPPs (African Development Bank Group, 2013). The 2018 Energy Sector Strategic Plan set the ambitious goal of achieving universal electricity access by 2024. The plan envisages rough parity in the shares of the population serviced by grid and off-grid energy power generation, with off-grid solar systems set to play an important role in rural communities. The plan explicitly recognized the importance of electricity access in schools and public institutions as a condition for the effective use of ICTs. (Republic of Rwanda, 2017b). Financial support for low-income households and communities to access off-grid solar energy is provided through the provisions of the 2016 Rural Electrification Strategy.

Innovation system weaknesses and constraints on transformative change

Kenya and Rwanda have been amongst the top-performing economies in Africa in terms of growth, with GDP growing In Kenya on average at 5.3% from its economic recovery in 2004 until 2019, and GDP growth in Rwanda averaging at 7.7% between 2000 and 2019 (World Bank development indicators). As we have discussed, both countries have actively pursued longer term visions of transformative change, and they have sought to align policies to benefit from the opportunities provided by digitalization/renewables for achieving such change. This does not mean, however, that there are no weaknesses in their innovation systems that constrain transformative change by limiting the ability of innovative firms to mobilize needed resources. Two areas where there is evidence of weaknesses in the innovation systems of Kenya and Rwanda are in the provision of needed skills and in support for building successful entrepreneurial ecosystems. Below we consider the evidence for weaknesses in these areas and identify the main policies and measures that have been implemented in response to them.

Skills development

Policies in support of ICT skills development have been implemented in both Rwanda and Kenya since the early 2000s reflecting the key role of the ICT sector in national development strategies. In Rwanda, government policy from the early 2000s acted to diffuse ICTs within the educational system from primary school upwards. At the higher education level, several ICT trainings programs have been established in major universities. A recent Ministry of Youth and ICT report refers, however, to a continuing big mismatch between the supply and demand sides of skills, particularly at professional and expert levels and notes that while all public and private universities and higher-level educational institutions offer ICT related courses they are of a general nature focusing on basic aspects of computer management and engineering at the undergraduate level and have failed to diversify towards emerging ICT

specialisations such as mobile computing and distribution systems (MINICT, 2016). In addition to a mismatch in higher levels skills there is evidence of an insufficient level of digital literacy in the public at large with only about 10% of adult estimated to be computer literate (MINICT, 2016).

These weaknesses are recognized by the Rwandan government and two key recent initiatives designed to strengthen ICT skills at both the technical and general levels are the Digital Talent Policy (MINCT 2016) and the Digital Ambassador program[17]. The former has a strong focus on addressing mismatches by increasing the number of formal educational programmes and the certification of ICT teachers, while the latter is more focused on increasing the level of ICT literacy and digital capabilities in the population at large, including a reduction in the critical ICT divide that exists between the rural and urban populations in Rwanda.[18] An initiative focused explicitly on enhancing research capabilities education is the establishment of the African Institute for Mathematical Science in 2016, offering courses in computer science and artificial intelligence.[19]

In Kenya, education policies have also since the mid-2000s placed a strong emphasis on ICT skills development with the 2005 Kenya Education Sector Support Program featuring ICT as one of the priority areas, aiming to mainstream ICTs into curriculum and teaching. More generally, the responsibility of the Ministry of Education for STI policy since 2013 has facilitated alignment between policies for ICT skills development and other policies related to STI development. By 2017 44% of primary and 60% of secondary schools had access to ICT for teaching and learning. Despite its strengths, there are recognized weaknesses and skills deficits that are known to affect and to be more pronounced in specific regions. A recent study by the International Trade Centre based on a survey of 893 businesses across Kenya in 2017-18 found that while the majority of employers were satisfied with the quality of their employees' skills, there were important skills deficits amongst SMEs in the rural areas and specifically in the south of Kenya (ITC, 2019). Another study by Cusolito and Cirera (2016), however, using a census of manufacturing firms and a large-scale services survey in Kenya, found evidence of pervasive skills deficits at the technical and managerial levels.

Initiatives to respond to skills deficits include the Kenyan Industry and Entrepreneurship Program (produced with support from the World Bank) and the Presidential Digital Talent Program. The former includes a component to directly support SMEs to improve their managerial and technical skills, and also for intermediary industry associations to identify SMEs for upgrading. The program also includes support for co-creation projects connecting

[17] See Digital Opportunity Trust (DOT). https://www.dotrust.org/media/2019/06/2019-01-04-DAP-Proof-of-Concept-Final-Evaluation-Executive-Summary.pdf

[18] See, for example, the recent #CONNECTRWANDA initiative providing 3000 female leaders of farming cooperatives with smartphones. https://www.minict.gov.rw/news-detail/digital-ambassador-programme-to-connect-5-million-rwandans

[19] See: https://aims.ac.rw/

innovative companies to students in secondary and higher-level educational institutions. The Presidential initiative is an internship programme that explicitly targets developing the supply of skilled ICT workers in Kenya through a collaboration between the public and private sectors. This public-private partnership is under the responsibility of the Ministry of Information Communications and Technology.[20] At the level of research capabilities an important initiative is the establishment of the Kenya Advanced Institute of Science and Technology, an advanced research institute to provide engineering and science training, scheduled to open in 2021.[21]

The governments in Kenya and Rwanda have clearly been active in their efforts to improve skills provision through a variety of initiatives some focusing on support for linking firms to education institutions and others aimed at increasing the capacity and quality of education and training institutes. While the pursuit of these policies indicate that the governments of Kenya and Rwanda recognize that responding to these problems are critical for achieving their visions for transformative change, the evidence shows that skills deficits and mismatches continue to constitute important constraints on development.

Developing entrepreneurship ecosystems

Although there is no agreed definition for what an 'entrepreneurship ecosystem' is, they are usually analyzed in terms of the relations that exist between a set of interdependent actors and organizations supporting the creation and growth of innovative firms. While there is clearly a bottom-up dimension of such systems of interdependent actors, state policies nonetheless play a role in supporting and sustaining them. Kenya is known for its vibrant digital innovation ecosystem, with multiple innovation hubs spawning several hundred digitally anchored start-ups (World Bank Group, 2019). A constellation of various actors has fostered Kenya's fast-growing start-up landscape, including foreign venture capital, global tech giants (such as Intel, Google and Facebook), international donors, supporting incubators, hubs and accelerators. Analyses of the entrepreneurship support system in Kenya nonetheless identify factors that constrain the creation and development of innovative firms. While the Kenyan ecosystem has performed impressively in terms of breeding digital start-ups, according to a recent World Bank report, its performance is less impressive in terms of supporting the move from the incubation stage onto sustained growth (World Bank, 2019). This may reflect problems with access to finance; since although Kenya has become an increasingly attractive destination for private equity investors and boasts several venture capital funds, SMEs are often credit constrained and find it difficult to access finance from banks or other financial institutions. Correspondingly they are typically dependent on raising funds from networks of friends and family. The government took some limited measures to

[20] See: https://digitalent.go.ke/

[21] See: https://konza.go.ke/2020/03/28/establishment-of-kenya-advanced-institute-of-science-and-technology-project/

improve access to finance for SMEs through the 2016 SME Act that imposed caps on interest rates. There has been debate about the effectiveness of this measure, and there was little evidence of improvement in credit access between 2016 and 2018 (ICT, 2019).[22]

The framework for Kenya's new Start-up Bill proposed in 2020 breaks with past practice by including tax incentives for those start-ups that are majority Kenyan-owned and focused on innovation.[23] However, to the extent that the core problem is one of longer-term sustained growth, this focus on tax relief may not go far enough. The recent World Bank-financed Kenyan Industry and Entrepreneurship Project takes a more systemic perspective on how to support entrepreneurship. It includes funds to finance competitively awarded performance contracts to entrepreneurship support organizations or intermediaries, including training provider and donor organizations, encouraging them to attract the best startups and talent. It also provides financial support for developing linkages and coordination within the Kenyan ecosystem and for connecting local firms to international networks of talent and support infrastructure (for example, mentors and early-stage investors) (World Bank, 2018). While the project has limited funding amounting to about 50 million USD, it may nevertheless serve as a model for future government-supported initiatives.

Kenya is recognized for the dynamism of its 'bottom-up' digital entrepreneurship ecosystem, while Rwanda is often identified as a case where the 'top-down' efforts of the government to promote private sector-led development have had limited success. The Rwandan government has taken the leading role in driving the development of the digital economy through its ambitious e-government strategy (World Bank Group, 2020). Some success in encouraging private sector investment in energy infrastructure has been achieved through government initiatives to create public-private partnerships to provide rural access to off-grid solar energy (Republic of Rwanda, 2017b). Further, while some limited success in promoting dynamic digital start-ups and entrepreneurship has been achieved through the support of NGOs and international organizations, it has been argued that the Rwandan system, much as the Kenyan, lacks the support infrastructure for start-ups beyond a certain growth stage, including incubators and accelerators which facilitate access to skills, networks, mentorship, and capital (World Bank Group, 2019).

The basis for these infrastructural weaknesses is discussed in a 2020 report that draws on a survey of entrepreneurship support organizations and start-ups undertaken by Credit Suisse in the context of a project to support the development of the Rwanda's entrepreneurship ecosystem (Credit Suisse, 2020). The report observes that the number of support organizations including accelerators, incubators and co-working spaces has increased in Rwanda recent years and that the density of such organisations per start-up is one of the

[22] For an overview of private equity, venture capital and impact investment in Kenya, see Divarkaran, et al. (2018).

[23] For the bill, see https://www.bowmanslaw.com/insights/intellectual-property/kenyas-senate-introduces-the-startup-bill-2020/

highest in Africa. While interactive learning amongst start-up firms occurs, the report argues that a key weakness in the system is the lack of connectedness and coordination among the support organizations resulting in a duplication of efforts and a lack of specialization. The report recommends the creation of a professional association of support organizations to increase communication and coordination of individual efforts and in this respect finds common ground with the emphasis in the Kenyan Industry and Entrepreneurship Project on developing linkages and connections among the actors.

5. Concluding remarks

The economic prospects of low-income countries have conventionally been framed as mechanisms that may support their transition to high-income status through copying technologies and practices in use elsewhere. However, the complex challenges and opportunities facing humankind today, as well as the urgency to move towards more inclusive and sustainable modes of development, point to the limitations of adopting such a lens. This paper argues that evolutionary economics lends us a more suitable set of tools to explore "path-breaking" modalities of development, relying in particular on the transformative power of digital technologies and renewable energies.

Seeking transformative outcomes becomes particularly urgent in contexts such as Africa where limited access to electricity and the Internet continue to impose major constraints on economic activities, the provision of public services, the adoption of new technologies, and the quality of life overall. More than 600 million people in Africa live without electricity, especially those residing in rural areas (80% rural households), and it is the region with the lowest Internet usage rates (28% of individuals using the Internet, as compared to 82% in Europe) (ITU 2019).

We have focused on the examples of Kenya and Rwanda to highlight the central role that governments can play in triggering such changes by establishing a national vision and institutional framework steering the direction of change and by mobilizing the support of multiple actors and stakeholders comprising the innovation and entrepreneurship ecosystems, which expand beyond national borders.

The innovation systems of Kenya and Rwanda continue to display important weaknesses that constrain notably the development of technological skills and capabilities as well as financial support for start-ups. However, both countries stand out for having recognized the opportunities ahead and for pursuing changes in their governance and institutional frameworks designed to achieve transformative change. For these reasons, they provide a possible point of departure for other developing countries.

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