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WIDER Working Paper 2014/062

Innovation capabilities for sustainable development in Africa

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March 2014

Abstract: A sustainable pathway for Africa in the twenty-first century is laid out in the setting of the development of innovation capabilities and the capture of latecomer advantages. Africa has missed out on these possibilities in the twentieth century while seeing the East Asian countries advance. There are now abundant examples and cases to draw on, in the new setting where industrial development has to have green tinges to be effective.

Keywords: Africa, sustainable development, innovation capabilities, green growth strategy, latecomer advantages.
JEL classifications: O14, 025, 033, 055.

Acknowledgements: An earlier version of this paper was presented in Beijing, December 2013. Tnd the authors thank Jean-Jacques Dethier, Alan Gelb, Akbar Noman, and Bichaka Fayissa for useful comments.

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This paper was prepared for the 'Oxford Handbook of Africa and Economics' authors' conference in Beijing, 8-10 December 2013, implemented with UNU-WIDER.Copyright © UNU-WIDER 2014

ISSN 1798-7237 ISBN 978-92-9230-783-7 https://doi.org/10.35188/UNU-WIDER/2014/783-7

Typescript prepared by Lesley Ellen for UNU-WIDER.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme from the governments of Denmark, Finland, Sweden, and the United Kingdom.

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1 Introduction

Africa's development in the twenty-first century clearly needs to be achieved in a setting of sustainable development and the development of innovation capabilities. As stated in the UN Conference on Sustainable Development, staged in Rio de Janeiro in 2012, the concept of sustainable development involves three dimensions; namely economic, social, and environmental dimensions. Among the three dimensions of sustainable development, economic sustainability is concerned with spreading prosperity and, as a result, reducing poverty. The second, or social aspect, concerns equity and has recently been formulated into emphasis on inclusive development. The third or environmental aspect is about the ecological and resource crises faced today and which threaten the development prospects of countries around the world.

While the three dimensions are all related to each other, we take science, technology, and innovation as holding a key to link them and having a potential of addressing effectively the problems in the three areas together (Lee and Mathews 2013).[1] This paper outlines ways by which Africa can build the innovation capabilities needed to address sustainability. It focuses on the role of learning mechanisms and channels of access to foreign knowledge to augment domestic capabilities as part of innovation systems. The paper is divided into four sections. The first section reviews the potentials of innovation in enabling sustainable development in its three dimensions. The second section examines Africa's latecomer advantages and the feasibility and necessity of switching to an alternative growth paradigm. Section three discusses and compares three different types of failures; market failure, system failure, and capability failure. The last failure is more unique to Africa and developing countries and prevents them from realizing their full innovation potential. The final section examines specific policy strategies in building up the innovation capabilities of African countries.

2 Role of innovation in fostering sustainable development

Innovation plays several roles in development in general and in sustainability transition in particular (Juma and Lee 2005). First, innovation can be a way to sustain economic growth in developing countries and Africa where people tend to experience short-lived growth only. Growth in developing countries tends to be short-lived because the global competitiveness of their products relies on cheap labour. Developing countries compete with each other by trying to offer low-priced goods, leading to declining prices. Second, innovation can reduce hunger and poverty by helping to increase agricultural productivity, thereby lowering food prices (Juma 2011). Third, innovation can promote sustainability by offering new environmentally-friendly modes of economic production and consumption. The inability of the conventional fossil-fuelled industrial model to scale up and spread prosperity demands an alternative model of sustainable development driven by innovation. Advancing a nation's capacity in innovation and its effective application in economic activities are, therefore, essential factors for expanding people's capabilities and achieving sustainable development. However, most African countries are lacking in innovation capabilities, which lead to 'capability failure' (Lee 2013b), a more serious problem than market failure (Cimoli et al. 2009) or system failure (Nelson 1993; Lundvall 1992; Metcalfe 2005).

[1] The term 'innovation' will be used in the rest of the paper to mean 'science, technology, and innovation'.

While some latecomer economies have been making a remarkable success of catching up, many others have not been able to join the catch-up club (Lee 2013a). While short-lived growth must be one of the causes of the poverty trap in low- or middle-income countries, it is also linked to the so-called 'adding-up problem'. The adding-up problem refers to the situation where many developing countries flood the market with similar goods that they tend to be good at producing, thus relative prices of these kinds of goods decrease, making these sectors less profitable (Spence 2011). For example, seeing some success of the flower industry in Kenya, several neighbouring countries are also jumping into the same industries, which are, to a certain extent induced by the flower purchasing businesses from the high income countries.

Adding-up problems are also serious in the case of labour-intensive, low-end goods production and exports in African countries. They compete with each other by trying to offer lower wage rates for assembly sites to attract foreign direct investment (FDI) businesses. However, some success with exporting industries with the original equipment manufacturing (OEM) arrangement tends to raise wages accordingly and eventually see their price competitiveness declining. Such businesses have to compete with next tier African countries which are able to offer cheaper labour to foreign investors (Lee and Mathews 2012: 223-48). Given such structure, processing industries in Africa cannot be certain about their long-term positions in global value-chains. One way out should be to move up to higher value-added activities in the same industries, which could support higher wages in activities the next-tier countries are not yet capable of executing. Otherwise, a country would experience growth slow-down and fall into the so-called 'middle-income trap'. It is a situation of being caught between low-wage manufacturers and high-wage innovators because its wage rates are too high to compete with low-wage exporters, and their level of technological capability is too low to allow them to compete with the advanced countries.[2]

We can reason that only when more successful African countries, such as Mauritius, move on from selling these low-end goods to the next stage of making, and selling higher-value-added or high-end goods, will they leave room for the followers to continue to sell low-end goods and maintain their footing on the development ladder. From this view, it is important for a country to quickly move beyond specialization in low-end or labour intensive goods to higher-end goods so that other followers may avoid unnecessary competition. This will also help to reduce tension among countries seeking to integrate their economies while producing the same classes of products. Such succession has happened in Asia, with the Korean and Taiwanese taking over the room left by the Japanese, and in turn, as these two advanced, the next-tier countries moved into the places left by Korea and Taiwan.

Similarly, innovation can help increase agricultural productivity which can then reduce hunger and malnutrition. One third of the sub-Saharan African population is chronically hungry. High food prices force people to purchase less food and less nutritious food. Growth in agriculture is at least two to four times more effective in reducing poverty and hunger than in other sectors because agriculture contributes 34 per cent of gross domestic product (GDP) and 64 per cent of employment (Juma 2011). A World Bank study has shown that caloric availability has a positive impact on agriculture productivity (World Bank 2008: 53). Innovation can help solve this problem by raising agricultural productivity.

Sustaining economic growth is important because growth is essential for creating jobs, spreading prosperity, and reducing poverty. Then, given the incidence of the adding-up problem and the related middle-income trap, we can see the need for innovation in making products from Africa

2 For similar definitions and more discussions see Lin (2012a, 2012b) and World Bank (2010, 2012).

differentiated from each other and higher value-added. However, innovation has been limited in Africa's economic growth despite its importance in sustaining economic growth. Furthermore, Africa is expected to find new or different modes of utilizing innovation for development because of the rising environmental costs of conventional growth models.

3 Latecomer advantages and Africa

Much of the research on technological development focuses on catching up in the mature industries. Freeman and Soete (1985) and Perez and Soete (1988) suggested the idea of leapfrogging, with a focus on the role of the new technological paradigm which stimulates the clustering of new industries. Emerging technological paradigms serve as windows of opportunity for the catching-up country. Because they are not locked into old technological systems, these countries can seize new opportunities from emerging or new industries. The area of information and communications technologies, especially in mobile telephones, has demonstrated the power of such windows of opportunity. Other emerging platforms such as genomics, biopolymers, and new materials offer similar windows of opportunity. In fact, the phenomenon of exponential scientific advancement and technological abundance provides Africa with more windows of opportunity than its Asian predecessors (Diamandis and Kotler 2012). Futhermore, Africa's heterogeneous market characteristics allow it to customize catch-up models to market size. The rise of regional integration and promotion of intra-African trade allows the continent to adopt diverse catch-up strategies that are suited to the different market sizes (Juma 2011).

Perez and Soete emphasize the advantages of early entry into the new industries during an early stage, such as low entry barriers in terms of intellectual property rights. This is because knowledge tends to reside in the public domain in the early days of new technology. Moreover, under such conditions there are no firmly established market leaders. In the initial stages of a new technological paradigm, the performance of technology is not stable and not dominated by a single firm. If there is adequate human capacity to access the knowledge and create new additional knowledge, entry into emerging technologies can be easier than during the later stages of technological evolution. The strategy of leapfrogging makes more sense during paradigm shifts because the incumbent tends to ignore new technologies and stay with existing dominant technologies (Lee 2013a).

African countries can capture latecomer advantages by adopting green technologies, leapfrogging the stage of 'carbon lock-in' that is holding back the developed world (Mathews 2013). Almost all the technologies involved in renewable power generation, energy efficiency, heat and power cogeneration, and development of alternative fuels and transport systems emanate from the advanced world. However, possibilities for applying them are found for the most part in Africa, where carbon lock-in does not act as a constraint. There is an historic opportunity for African countries to build new industrial systems based on renewable energies and resource efficiency that will generate advantages for the countries concerned (and serve as export platforms for their future development) as well as providing a pathway of sustainable development to the rest of the world.

It is a period of opportunity for the entry of African firms, especially when they have government research and development (R&D) support and financing. Newly-emerging or short-cycle technology sectors do not automatically mean that there are no entry barriers. It takes sustained technological effort to harness such emerging opportunities. For example, the wind turbine industry in China and India used to be dominated by European firms. With local technological effort and government support, including local contents requirement on FDI firms, local firms have made a significant and successful entry into the sector (Lema et al. 2012).

Market-based approaches are often not adequate to bring in the new technologies needed to replace unsustainable old ones in time to avert irreversible environmental damage (Altenburg and Engelmeier 2012). Policy intervention may, therefore, be justified in correcting market failures and making green technologies more profitable than less sustainable ones. One way to make them profitable is to create artificial rents (for example, through smart subsidies) to lure capital into socially-desirable green investments. In other words, temporary rents can induce deployment of green technologies, thereby spurring technological learning and allowing producers to reap benefits from economies of scale. Now, an emerging literature indicates a revival of industrial policy, such as Lin and Stiglitz (2013) and Aghion et al. (2011). However, using rents as incentives also risks misallocation and political capture. Such instruments need to be managed carefully with a clear timetable for future withdrawal (as was done with rents flowing from government subsidies in East Asian countries).

4 Capability failure as a barrier to innovation

Development is more about capability building than it is about optimizing given resources (Lee and Mathews 2010). Then, we can reason that neoclassical economics cannot be good development economics because it is all about optimization or optimal uses of existing resources. It also implicitly assumes that all resources are accessible and we only have to consider how to utilize them most efficiently (Nelson 2008). In reality, for most African countries, what matters more is not to use resources in an optimal way but how to build up various capabilities, especially the private sector (Lee and Mathews 2010).

Typical market failure justification of R&D subsidy arises from the perceived positive externality of R&D and its resulting undersupply (Greenwald and Stiglitz 2013). In this view, firms are assumed to be capable of conducting R&D. The problem is considered to be simply about their inability to produce the optimal amount. The reasons for this are sought outside the firm, such as in the capital market or risk market, where government's corrective action is recommended.

However, in most developing countries private firms are unable to pursue and conduct in-house R&D. They consider it an uncertain endeavour with uncertain returns. Thus, the problem is not less or more R&D but 'zero' R&D. In fact, R&D-to-GDP ratio becomes flat among the middle-income countries, which means that they are not paying enough for R&D (Lee 2013a). This is serious because middle-income countries are the ones that should start paying more attention to innovation. This suggests that failure to innovate is the root of the middle-income trap, as verified by Lee and Kim (2009).

In contrast to the typical argument for government activism based on market failure or system failure, 'capability failure' is a stronger justification for government activism. In African countries, where firms have a low R&D capability, a safer way of doing business is to buy or borrow external technologies or production facilities and specialize in less technical methods or assembly manufacturing. To move beyond this stage, effective forms of government activism are needed, not simply by providing R&D funds but by using various ways to cultivate R&D capability itself.

As shown in the case of Thailand, there is a tendency for government policy to be limited only to providing tax incentives without implementing explicit measures to encourage firms to take on greater risks to innovate (Chaminade et al. 2012). More effective and alternative forms of intervention include transfer of R&D results from universities, public research institutes, and public-private R&D consortia to enterprises. This has been used widely and successfully in

Korea and Taiwan.[3] Such direct intervention is important because learning failure happens not only due to the fact that knowledge is a public good but also because of the absence of opportunity for effective learning. This is often due to inherited conditions or policy failure. Higher technical training is also essential for building the capacity needed to make the sustainability transition (Juma 2007).

In this respect, industrial policy is not about choosing winners but about choosing good students and matching them with good teachers or bringing them to good schools. Good schools may be in the form of licensing-based learning (of tacit knowledge) or public-private joint R&D projects, in which direct and cooperative learning take place. By contrast, institutions that merely supply R&D funding might not serve as good schools. Expanding this analogy, market failure can be expressed as: 'I will pay for your school so that you may take more classes'. System failure (Metcalfe 2005; Bergek et al. 2008; Dodgson et al. 2011), on the other hand, may be expressed as: 'Go to school and make more friends'. Neither view pays enough attention to key factors such as the initial aptitude of students, what is taught to them in schools, who the teachers are, and how they teach their students. In the capability view, these aspects are crucial to a successful industrial policy. Thus, the capability failure view is essentially about the importance of raising the level of capabilities of the firms (students) and the various learning methods to be provided during the dynamic course of learning. In sum, both tuition fees (R&D funds) and good friends (linkages to other components in the system) in schools are needed, but the critical factors are the students themselves, a good curriculum, a knowledgeable teacher, and an effective teaching method or pedagogy.

Table 1: summarizes the aforementioned arguments

	Market failure	**System failure**	**Capability failure**
Focus	Market institutiions	Interaction among actors	Actors (firms)
Source	Knowledge as public good	Cognition failure from tacitness of knowledge	Historically given No learning opportunity
Example problem	Sub-optimal R&D	Lower R&D effects	No R&D
Solutions	R&D subsidies	Reducing cognitive distance	Access to knowledge and help in learning
School analogy	Tuition support	Making more friends	Targeting student learning
Relevance	Africa and advanced countries	Africa and advanced countries	More unique to African countries

Source: Based on Lee (2013b).

5 Building innovation capabilities[4]

[3] For details, see Mathews (2002), Lee and Lim (2001), and Lee et al. (2005).

[4] This section draws heavily on Lee and Mathews (2013).

5.1 Stages of learning and capability-building

There are several stages of learning and capability-building which eventually involve the final stage of leapfrogging. In the initial stage, latecomer countries tend to specialize in mature industries. An example is textile products where latecomers produce for export markets via an OEM arrangement with firms from advanced countries. OEM is a specific form of subcontracting under which a complete, finished product is made to the exact buyer's specifications. Examples of the OEM or FDI-based assembly-type products include consumer electronics, automobiles, and telecommunication equipment. These arrangements are typical of low-income or middle-income countries. From the 1970s to the early 1990s, OEM accounted for a significant share of the electronic exports of Taiwan and Korea, and served to facilitate technological learning (Hobday 2000: 129-69).

In this mode of learning-by-doing or exporting, the by-products are job creation and foreign exchange earnings, and the policy tools often include tariffs and undervaluation of currencies that are less sector-specific or horizontal. A desirable structure of tariff may be asymmetric structure, such as higher tariffs for sectors that are being promoted and lower tariffs for imported capital goods. Such asymmetric tariffs increased the world market share of Korean products (Shin and Lee 2012). Other forms of horizontal interventions are needed to build physical infrastructure. While the OEM is an effective way of catching up at the early stage of economic growth, it is somewhat uncertain as a long-term strategy because foreign vendor firms may move their production orders to other lower-wage production sites (Lee 2005). Currently, a similar trend is underway among flower producers in East Africa as foreign vendor firms buy flowers not only from Kenya but also from neighbouring countries catching up with Kenya.

In this respect, OEM firms should prepare longer-term plans to transition to original design manufacturing (ODM) and finally to original brand manufacturing (OBM). ODM firms carry out most of the detailed product design, and the customer firms of ODM companies continue with marketing functions. Meanwhile OBM undertake manufacturing, design of new products, R&D for materials, processing of products, as well as sales and distribution for their own brand. The path from OEM to ODM to OBM has become the standard upgrading process for the latecomer firms. Modified examples of such upgrading in flower firms in Africa would be producing flowers that can last longer, have specific smells, and use less pesticides. All these require innovation. A transition to OBM in the flower industry would require African firms to enter into marketing and set up their own outlets with their own brands in Europe. Such a transition to ODM or OBM is not easy but serves as a narrow path to the middle- or even higher-income status. Another model available for African countries, endowed with rich resources, is a combination of 'black' and 'green' development, where cash from exports of natural resources can be used to finance entry into green industries (Lee and Mathews 2013).

In general, transition to the middle-income stage and beyond calls for more sector-specific or vertical intervention policies. This is because the country must identify its niche between low-income countries with cost advantages in low-end goods, and high-income countries with quality advantages in high-end goods. At this stage, public policy should focus on two kinds of upgrading: entry into new industries, and upgrading to higher value-segment in existing industries, which is to upgrade the overall industrial structure (Lee and Mathews 2012). Short-cycle, technology-based sectors are candidate niches for latecomers (Lee 2013a). The main issue is how to break into medium short-cycle technology-based products or into the higher-valued segment of the existing sectors. Good targets for such an (import substitution) entry are those products that latecomers have to import at higher prices due to oligopolistic market structure, dominated by incumbent countries or firms. A best existing example is China's telephone switch development in the 1980s and 1990s (Lee et al. 2012: 21-71). The lessons have implications for African countries which produce oil but export it as crude oil without refining it. They can build more oil refineries based on mature or medium short-cycle technologies. The task is possible since the technology needed to build oil refineries is old, mature, and easily available at cost. The process would be similar to the Korean entry into steel-making through a state-owned enterprise in the early 1970s.

The final stage of leapfrogging involves public-private R&D efforts that target emerging rather than existing technologies. In this case, the role of the government, research-oriented universities, and public laboratories is to share the risks of the choice of technologies and promote initial market creation. Specifically, coordinated initiatives on exclusive standards and incentives for early adopters are essential in reducing the risks associated with weak initial markets. Examples of this strategy can be found in the renewable energy markets of China, Brazil, and India which involve the transition toward low-carbon economies. Options for Africa in low-carbon technologies include wind, solar, biogas, and geothermal energy sources.

An example is the use of solar power in desert grasslands rural areas in the Jigawa state of Nigeria. Given no water supply in this semi-desert area, a traditional option was to open wells with rope and bucket, hand pumps, or government supplied diesel-powered pumps that work only until they break down or until villagers run out of money to buy the expensive diesel. Now, solar-powered pumps have solved the problem as they are designed to run maintenance-free for eight to ten years or more.

Another example is the O&L Groups in Namibia. Established by Mr. Shilongo, this company started from retail and brewery, and then diversified into dairy and even solar energy. Owing to government support (against a South African company's price-dumping to kill this company), they survived, grew big and quickly, with their sales reaching about 4 per cent of GDP of that country. In this sense, this conglomerate can be a called a 'Samsung' of Namibia. Given that Namibia imports electricity from South Africa and Angola, this company plans to enter more into energy business, including wind power, although they have first to solve the hurdle imposed by grid monopoly by the government.

Some example cases in Africa are really more about adoption of new technologies than local innovations. But adoption is a beginning or stepping stone for learning and eventual innovation. Without adopting, you cannot learn. Manufacturing in East Asia, such as Samsung and Hyundai Motors in Korea, all started from the adoption of foreign technology for production, learning from using it, finding a way to enhance productivity by mastering production technologies, and finally even acquiring design technology (R&D capability) to be able to conduct their own machinery and equipments (Lee 2005, Lee 2013a).

5.2 From the government-private-government (GPG) model to foreign actor-local firm-government (FLG) model of learning

The three stages in the above scheme can be further elaborated with focus on the changing roles of government research institutes (GRI) or public research organizations (PRO). The essence of such a latecomer model of technological development is the tripartite cooperation involving government research institutes, private firms, and government ministries (GPG). Under this model the actors have different roles depending on the stage of development. Every technological development should involve R&D, production, and marketing. This implies that government research laboratories are in charge of R&D, private firms of undertaking production, and government ministries of marketing in the form of direct procurement or protection by tariffs and exclusive standards.

The case of the telephone switch in Korea and China would be the most typical representation of this model. Under this model (let us call it GPG1) R&D is mainly done by GRIs or public research organs (Table 2). Private firms are in charge of manufacturing and the government helps marketing through procurement of the domestically-made products. There are other variations on the model depending on the level of capabilities in private firms and the public agencies involved. The case of digital TV and CDMA mobile phones in Korea is another variation that can be called a GPG2 (Lee et al. 2005). In the GPG2 model, the costs and risks of R&D are shared between government research institutes and private firms, and the GRIs play the role of technology-trend watching and coordination to bring diverse actors into the consortium. The GPG2 model is a more advanced form of the GPG arrangement. It is only possible when the capabilities of private firms are advanced enough to undertake more R&D.

Table 2: From government-private-government (GPG) model to foreign actor-local firm-government (FLG) model

1st stage	**GPG0**	**F-L-G0**
Tech transfer/R&D	PRO/foreign actor	Foreign cooperation partner
Production	*SOEs/private firms	Local firm (private, SOEs)
Market promotion/protection	Government	Government
2nd Stage	**GPG1**	**FL-P-G2 (FLG1)**
R&D	PROs	Joint R&D by foreign & local PROs/firms
Production	Private firms	Local private firms
Market promotion/protection	Government	Government
3rd Stage	**GPG2**	**G-P-G2 (FLG2)**
R&D	Public & private joint R&D	Local public & private joint R&D
Production	Private firms	Local private firms
Market promotion/protection	Government	Government
4th Stage	**GPG3 (PG)**	**G-P-G3 (FLG3)**
R&D	Private firms	Local private firms
Production	Private firms	Local private firms
Market promotion/protection	None	None

Note: *state-owned enterprises (SOEs).

Source: Based on Lee and Mathews (2013).

Another variation of the GPG model is the case of government agencies doing both R&D and production. This is possible when capabilities of private firms are low or the projects involve more production and less R&D with some start-up costs. This variation can be called GPG0, though it is actually not GPG but GG without P (without involvement of private firms). Steel development in Korea by the government-owned enterprise, POSCO, is an example.

The opposite case to this GPG0 model is that of GPG3 or PG, where the government research institute is missing. An example is the case of the development of the automobile industry spearheaded by Hyundai Motors. In this case, the government, or a government research institute, was not involved in R&D and its role was limited to providing protection of the infant industry by tariffs (Lee and Lim 2001). Since R&D was done by private firms or Hyundai Motors, this is a GP rather than GGP model, where private firms do both R&D and production.

Based on the Korean experience, there are four models of state activism for technological development with increasing private sector participation. First, there is the GPG0 (or GG) model where the government does market provision and state-owned enterprises undertake both R&D and production. Second, in the GPG1 model, R&D is done and GRIs and production are undertaken by private firms. Third, under the GPG2 model, more R&D is shifted to private firms which cooperate with GRIs. Finally, the GPG3 (or PG) model has private firms doing both R&D and production. In all of these variations, the role of the government (or ministries involved) tends to focus on guaranteeing initial market creation in the form of procurement policies and local market protection by tariffs or exclusive setting of standards.

In the above discussion, the focus has been on the roles of government ministries or research laboratories. However, one common element across the four models of technological development is that they all involve accessing foreign knowledge in diverse channels. In this regard, foreign knowledge is critical, without which the latecomers' catching-up effort is often at risk and takes too much time and costs (Lee 2005). In general, the diverse channels of knowledge, access, and learning include such modes as: training in foreign firms and institutes, OEM, licensing, joint ventures, co-development with foreign specialized R&D firms, transfers of individual scientists or engineers, reverse brain drain, overseas R&D centres, strategic alliances, and international mergers and acquisitions (Lee 2005). Successful technological development by latecomers tends to involve government support, access to foreign knowledge, and private firms' effort. The weight and specific role of the three elements differ by sector and level (or stage) of economic development.

The above GPG model can be modified as the model of international technology assistance for African countries. This can involve cooperation between foreign actors, local firms, and government (FLG). A simple idea of this is to put foreign actors (foreign research organizations invited by the donor government or the United Nations) in the place of the GRI/PRO in the GPG model so that foreign actors (cooperating partner) conduct R&D to transfer the results to local (private or state-owned) firms in African countries (stage FLG0). Then, in the next stage or FLPG, foreign partners conduct joint R&D with local R&D organizations or firms. Then, in the third stage, the aid-receiving African country is able to conduct R&D locally through private-public partnerships, which is equivalent to GPG2. The final stage is, of course, where all functions are performed by private actors.

The Green Revolution of the 1960s and 1970s and the System of Rice Intensification (SRI) are examples of the FLG model. The Green Revolution involved the introduction of packages of high-yielding varieties of: rice, wheat, and maize; fertilizers; pesticides; new management practices; and irrigation. The packages brought about a dramatic increase in productivity and production. The Green Revolution, initiated with support from the Ford and Rockefeller Foundations and led by Norman Borlaug, is regarded as having saved over a billion people from starvation. Much of the initial research on rice and wheat has already been done in American universities but needed to be adapted to local conditions. This required the creation of new international research institutes, initially the International Maize and Wheat Improvement Center (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines

(Juma 2011). These institutions were later brought under the auspices of the Consultative Group on International Agricultural Research (CGIAR). Today the CGIAR is a consortium of 15 research institutes working on agroforestry, biodiversity, dry areas, food policy, fish, forestry, livestock, maize and wheat, potato, rice, semi-arid tropics, tropical agriculture, and water. As part of this international initiative, local authorities expanded roads, improved irrigation systems, and provided electrical power to support farmers to adopt the new technology. International lending was also made available to promote the package. Research collaboration at the international level also led to the birth and expansion of national agricultural research institutes. These centres were to adapt the internationally developed varieties of rice and wheat to local conditions.

In the Indian case, the government played a key role in the diffusion of new seed varieties. The government, with the financial support from the World Bank and technical assistance from the Rockefeller Foundation, established state seed corporations in most major states in the 1960s which led to the creation of the seed industry in India (Juma 2011). SRI was started in the early 1980s after participating groups from 40 countries first assembled in Madagascar in 1983. Then, it rapidly spread to more countries with the assistance of Cornell University. India is regarded as one of the biggest beneficiaries of this initiative.

6 Conclusions and implications

This paper has argued that innovation can play a critical role in expediting the transition to a sustainable mode of development, especially through industrial restructuring and fostering of green growth. A critical concept in this transition is leapfrogging including stage-skipping whereby the African countries can jump into a new ecofriendly techno-economic paradigm. The concept of green growth has an intuitive appeal because it is the developed countries that have the most infrastructural inertia in terms of 'carbon lock-in' whereas African countries have the opportunity to leap to new green innovation systems that are unconstrained by such lock-in. They also have powerful competitive advantages based on their abundance of resources (sun, land, and water) which can be utilized as sources of energy, both to power the industrial development of the latecomer itself and also to provide an export platform—as demonstrated clearly by China (Mathews and Tan 2014).

The revival of agriculture also offers new opportunities to leapfrog into green technologies. For example, Burkina Faso adopted insect-resistant, genetically-modified (GM) cotton that has significantly reduced the amount of insecticides that would have been used if it had pursued older production methods (Vitale et al. 2010). In fact, the country was able to skip the first generation of GM cotton and go straight to the second generation that used stacked genes. Such leapfrogging cannot be done without the existence of the local research capabilities needed in the various stages of the cotton production value chain.

Indeed, if African countries want to undertake such leapfrogging in areas of green innovation, they need to build up technological capabilities and access the vast fund of knowledge available in other countres around the world (Juma 2012). It is not enough to simply focus on technology acquisition and foreign direct investment. Efforts must be made to promote indigenous innovation, utilizing public research institutions as well as universities. The next step is to promote the diffusion of new clean and green technologies through incentives that stimulate their uptake by new local sectors. Brazil's biofuels programme, with its emphasis on providing rural employment, and its building of a national domestic value chain for bioethanol and biodiesel production, is an example of the social inclusiveness that can be generated by green growth strategies. Africa can pursue such strategies in areas such as solar photo-voltaics and wind power.

To sustain economic growth, the re-balancing of the development agenda should emphasize not only infrastructure or business climate improvement but also cultivation of private firms and their innovation capabilities. Thus, African countries should be allowed policy space to nurture their local firms. Local firms are unlikely to emerge and flourish if they are exposed from the beginning to competition with foreign goods. Having elementary school players competing in the same soccer tournament with the professional players is not a fair game. To further facilitate the cultivation of firm-level technological capabilities, the international organizations such as the World Bank and the United Nations may consider starting new initiatives to promote local-foreign partnerships (LFPs). This can be regarded as a modification of private-public partnerships (PPPs) involving R&D consortia. While the latter involves private firms and public research facilities, as was successfully practised in East Asia, LFP involves private firms in less developed countries cooperating with public R&D units from industrialized countries to solve production problems. The approach can also be used to implement new business ventures for import-substitution or export-generation in mature or emerging technology sectors.

An international assistance programme that might be called 'Innovation Corps' can be launched to help firms in Africa. The innovation members would be a team of foreign experts from public R&D units, retired engineers from the private sector, and policy practitioners from foreign governments. Such teams can help solve technical bottlenecks in African country firms in the area of innovation and management consulting and know-how. The Korean government has promoted such programmes to help small and medium-sized enterprises. The United Nations Industrial Development Organization has a similar programme that can be expanded.

There are many examples of technological leapfrogging that have been practised around the world including in Africa and have had tangible impacts on patterns of production and consumption. However, a greater policy intervention is called for to expedite the diffusion of new technologies needed to maintain the upgrading momentum. Various forms of incentive are needed to correct market failures and coordination failures and to achieve economies of scale. The international community may consider setting up a global fund to support R&D into new environmentally-friendly technologies and to promote their diffusion.

In sum, this paper has argued that green growth is a feasible goal for African countries, enabling them to create a sustainability path, with a part of the revenue from exporting raw materials, from 'black to green' development. Green growth offers the best chances for social inclusiveness, given that many sources of renewable energy will have to be developed in rural areas and can offer employment and social infrastructure development for rural communities. This is a promising way forward for African countries. But to achieve it Africa will have to focus its long-term attention on building innovation capabilities.

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