Africa's nanofuture: the importance of regionalism

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Abstract: In the quest to be part of the global revolution in science, technology and innovation at the nano-scale (STI-NANO), African countries should cooperate on a regional basis. This paper discusses the problem of funding nanotechnology research in Africa and argues that regionalism as an overarching policy framework can help address the problem. The proposed policy approaches are evaluated based on affordability, resource mobility, awareness, acceptability and sustainability. The paper offers recommendations for Science, Technology and Innovation (STI) to secure a nanofuture for Africa.

Keywords: regionalism; innovation; nanotechnology; epistemic communities; collaboratory; leapfrogging.

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1 Introduction

Regional integration presents growing opportunities for Africa's scientific and technological renaissance. A well-organised integration offers the platform for developing and sharing infrastructure for scientific and technological research and development (R&D), and for mobilising and using the limited expertise and financial resources available [1]. Applications of science, technology, and innovation at the nano-scale (STI-NANO) have been predicted to change our way of life and transform human society in very significant manner. Human and animal health, trade, agriculture, environment, national security, and economic growth and sustainability could all be influenced by STI-NANO developments and applications [2]. There are grave concerns about the real and perceived risks, safety and ethics. Despite these concerns, there is the optimism that the effects of STI-NANO will be mostly positive and the associated risks can be well managed.

The US National Nanotechnology Initiative (NNI) defines nanotechnology as

> "the understanding and control of matter at dimensions of roughly 1 nm to 100 nm, where unique phenomena enable novel applications … At the nanoscale, the physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter. Nanotechnology R&D is directed toward understanding and creating improved materials, devices, and systems that exploit these new properties."

Application of nanotechnology means using lesser quantities of raw materials than the traditional use [3]. This may contribute to environmental protection and sustainable developments through limited use of resources, reduced generation of waste, and thus, reduced level of payments for environmental services. Successful incorporation of STI-NANO applications in the agrifood and medical sectors could improve land use by enhancing yield to land ratio, and improved life expectancy and boost quality of life [2].

African countries will need strong regional cooperation and links with viable institutions in developed and middle-income countries to establish a good R&D foundation in STI-NANO. The challenge is that African countries have not been able to take advantage of advances in previous emerging technologies like biotechnology and Information and Communication Technologies (ICTs), and are still struggling to determine how STI can advance their economies [2]. To meet this challenge, there must be a conscious effort to invest in STI in the face of pressing and legitimate competing demands for investment in education, healthcare and infrastructure (roads, electricity, water and ICTs) [2].

Nanotechnology product and process applications are being developed globally in the life sciences, medicine, electronics, optics, information technology, telecommunications, aerospace and energy. Typically, many underlying progenitor technologies contribute to nanotechnology advances. These technologies are based in sciences including molecular biology, electronics, materials science and physics (optics and quantum). Nanotechnology is thus built upon many sciences and is inherently complex. This necessitates the training and support of researchers capable of technological integration, and requires high levels of government support in training, funding and infrastructure.

In addition to the problem of funding of nanotechnology research, Africa faces the problem of responding to the distribution and diffusion of engineered nanomaterials, including commodities, instrument facilities and services, and how to face the challenges these change will bring on the African society. Many obstacles prevent priority technologies from reaching widespread use and acceptance. These include low profit margins in developing world markets, regulatory constraints and the need for systems changes. These are the primary reasons for which the African Union was established. Among the several objectives of the African Union is to "advance development of the continent by promoting research in all fields, particularly in science and technology" [4].

2 STI-NANO: market potential and global efforts

According to MarketResearch.com®, RNCOS [5] earnings from STI-NANO products show promise:

- The market for nanoelectronics is projected to reach $4.219 million by 2010 from a total of $1.827 million in 2005.
- The nanofood market is expected to rise from $6.311 million in 2006 to $20.40 billion by 2010 with a 30.94% Compound Annual Growth Rate (CAGR) [6].
- The market for textiles using nanotechnology is projected to reach $115 billion by 2012, from an estimated $13.6 billion in 2007.
- The US market for nanotech tools is forecasted to triple from $900 million in 2008 to $2.7 billion by 2013 at a rate of nearly 30% per year.
- The USA is the global leader in investments in nanotechnology R&D. As at 2005, the USA held 28% of the global market, followed by Japan with 24% of the market share. Major investments from countries such as Germany, the UK and France gave the European Union (EU) 25% of the market. Other countries such as China, South Korea, Canada and Australia held the rest of the market share.

The USA initiated a national nanotechnology strategy in 2001 as recognition of the inherent potential of STI-NANO, whereas the EU integrated its strategic nanotechnology and nanoscience initiative with the zeal for global leadership in ICT-led economic development [7]. Three billion Euros has been allocated over the next 10 years for nanoelectronics research alone [8]. China has exhibited its seriousness about STI-NANO by initiating and hosting the "China International Conference on Nanoscience and Technology" in 2005, 2007 and 2009, with high-level governmental participation [9]. These conference series are predicated on the assumption that it offers prospects for acquiring cutting-edge knowledge while enhancing the capacity of the host communities to be part of generation and evolution of the global STI-NANO knowledge. India's selection of Bangalore, Kolkatta and Mohali as new nanotechnology centres demonstrates how important India sees the economic potential of STI-NANO [10]. Brazil began showing interest in STI-NANO in 2000 and in 2004 STI-NANO was integrated into a multi-year development plan (2004 2007) [11]. According to the president of the Korean Nano Researchers' Association [12], investment in STI-NANO started on a national scale in 2001. South Africa has also shown deep interest in STI-NANO. The hosting of the "2007 World Nano-Economic Congress [13]" demonstrates this interest. Countries such as Argentina, Chile, Mexico, Philippines and Thailand are all involved in this new frontier science [14]. Iran has adopted a nanotechnology programme with a focus on agricultural application and had already commercialised 'Nanocid', a powerful antibacterial product with potential application in the food industry [15]. The list of countries investing and showing great interest in the economic potential of STI-NANO reveals a healthy mix of developing and developed economics. However, African countries, with exception of South Africa, are missing from the list.

3 Africa's science, technology and innovation nanofuture

Researchers have successfully explored the definitions of innovation, innovation theories, the rationale of government interventions on innovation, innovation policy instruments and the relationships among new technologies, emerging markets, innovative services and economic growth [16]. However, there are different conceptions of what constitute the core elements of a national innovation system [17]. Innovation is the combination of knowledge that results in new products, processes, input and output markets and organisations [18]. Innovation includes not only technical innovation, but also organisational and managerial innovation new markets, new sources of supply, financial innovations and new combinations. Innovation is a critical factor in enhancing a nation's competitiveness. National governments have crafted innovation policies to improve their nation's growth.

Industrial innovation includes

> "technical design, manufacturing, management, and commercial activities involved in the marketing of a new or improved product or the first commercial use of a new or improved process or equipment." [19]

Although there is little discussion on the steps through which innovation policies are formulated, effective implementation and design of an innovation policy determines how successful the policy becomes. There are no universally agreed laid down procedures for innovation policy-making. What happen in most democratic countries is that, stakeholders are made to debate and discuss policy issues as part of the policy formulation process. In some other countries, groups of experts are brought together to form the so-called national advisory councils or science technology advisers, while others depend mostly on external experts or consultants [20].

Much has been written about the potential of nanotechnology to help solve many of the problems confronting Africa [21]. National governments, industries and non-governmental organisations (NGOs) are all describing nanotechnology as 'The Next Big Thing' [21] (p.0384). Nanotechnology is also bedevilled with uncertainty about risks, ethics and benefits to the resource-poor who more often than not are excluded from conversations about the societal implications of new technologies. Although the potential benefits STI-NANO presents to Africa are very exciting, so far too little interest has been shown to the specific needs of people on the continent [22].

According to a recent study by the Canadian Program on Genomics and Global Health (CPGGH) at the University of Toronto Joint Centre for Bioethics (JCB) [23], there are numerous existing and potential nanotechnology applications that will help developing countries to confront many of the most urgent problems, specifically, extreme poverty and hunger, maternal, child and neonatal mortality, environmental degradation, and debilitating diseases such as malaria and HIV/AIDS. The study is the first of its kind to rank nanotechnology applications relative to their developmental impact [21]. The study used the world's eight Millennium Development Goals, agreed by the

United Nations in 2000 for achievement by 2015 as the measure of the potential the impact of nanotechnology [24].

The CPGGH study identified and ranked the 10 nanotechnology applications most likely to have an impact in the developing world. An international panel of 63 experts was asked to rank which nanotechnology applications are most likely to benefit developing countries in the areas of "water, agriculture, nutrition, health, energy, and the environment in the next 10 years". The top-ranked nanotechnology applications were:

1 "energy storage, production and conversion
2 agricultural productivity enhancement
3 water treatment and remediation
4 disease diagnosis and screening
5 drug delivery systems
6 food processing and storage
7 air pollution and remediation
8 construction
9 health monitoring
10 vector and pest detection and control" [21] (p.0384).

Clearly, STI-NANO is not a 'silver bullet' that will magically solve all the problems of Africa [25]. Yet to maximise the positive impacts of nanotechnology, Africa will need to embrace regionalism.

4 Regionalism

Regionalism is the process of opening up and integrating socio-economic and political systems across national borders in neighbouring nations. It is a mutual process between nations of specific jurisdictions to promote interstate security, economic activities and exchange [26]. Regionalism in Africa dates back to the 1960s when it was recognised by leaders of newly independent states to promote economies of scale in production and gain greater bargaining power in world trade relations through trading within regional economic blocs [1]. It is, therefore, not a new phenomenon. To date, there are only few real cases of regional cooperation in Africa designed to take advantage of the advances in science, technology and innovation (STI) in order to solve common development problems, despite the acknowledgement of the significance of regional cooperation [1]. S&T collaboration provisions in regional agreements have for the most part remained statements of intent, a typical example being the Lagos Plan of Action [27]. They have generally not yielded projects and programmes. The few attempts at implementing policies including regional treaties have not been successful. Regional integration in Africa clearly needs to be re-examined, from the perspectives of past performance and the globalisation process, starting with the very mixed institutional performance of the Regional Economic Communities (RECs) [28]. The most important RECs include:

> "Community of Sahel-Saharan States (CEN-SAD), Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC), Economic Community of Central African States (ECCAS/CEEAC), Economic Community of West African States (ECOWAS), Southern African Development Community (SADC), and Arab Maghreb Union (AMU/UMA)."

The problems that have plagued these regional blocs include: competing demands on RECs by member countries which, in many cases, belong to more than one REC; lack of compensating mechanisms for losers in the process of integration; weak national commitment in terms of practical implementation of agreed policies; weak capacity at the national and sub-regional levels, to implement regional programmes and regional conflicts.

Despite the problems historically associated with regionalism in Africa, S&T can lead the way in promoting regional integration. The concept of regionalism creates opportunities for countries with less endowed STI capacity and infrastructure to articulate their quest for technology, design innovation policy, and make the required institutional changes [1]. The opportunities created by regionalism if well structured and managed will boost the confidence of Africa in its capacity in knowledge creation for socio-economic and human resource developments [1].

5 Policy framework

The role that emerging technologies generally, and more specifically STI-NANO, can and should play in developing countries and for the poor is a continuing debate. Nanotechnology development will pose risks and costs in addition to opportunities and benefits to poor people. There is the need for an overarching policy framework by African governments and regional groupings to address these issues. An adequate policy framework must address five critical issues: affordability, resource mobility, awareness, acceptability and sustainability.

Affordability

If nanotechnologies are to aid poverty reduction, the technology and products have to be affordable. Countries will need the financial resources necessary to supply a technical infrastructure and those necessary to create demand for the technology. Without the right conditions, there will be no demand for the technology. The ability to access new technologies will depend on the type of policy framework that is put in place.

Resource mobility

Unfettered resource mobility is crucial in obtaining new technology adoption, which requires an appreciable level of investments in learning, management, equipment and new relationships, all of which involve some uncertainty and irreversibility of investments [29]. The extent of irreversibility is subject to the intrinsic features of the new technology and the price-cost environment of the activity to which the technology is applied and the policy framework in place.

Awareness

The number of people who are aware of nanotechnology, and who they believe should monitor the safety and effectiveness of products that are being greatly impacted by nanotechnology is very important in the deployment of nanotechnology and diffusion of nanoproducts in Africa [30]. Therefore, the policy framework should address issues such as capacity building, rural livelihoods and income generation activities that have both direct and indirect, positive effects on communities. The policy framework should help create awareness of nanotechnology among stakeholders.

Acceptability

The policy framework should make nanotechnology socially, culturally and politically acceptable. The framework should be able to foresight how the reality will look like as Africa's nanofuture appears to be a long way off from current point of view.

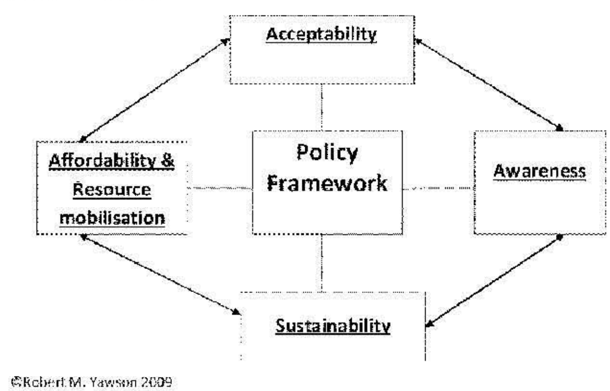
Sustainability

The policy framework should help make nanotechnology sustainable, robust, and adjustable to settings in African countries. The nanotechnology policy should promote local R&D and local ownership. Solutions must be technologically, socially, and environmentally feasible and sustainable. The policy should also be able to facilitate the development and building of economic and technical infrastructure and capacity to sustain the technology.

The policy framework diagram in Figure 1 shows these critical issues in diagrammatic form. Lines have been drawn to show the relationships among the issues and how the policy framework is central to their resolution.

As policy-makers examine the future economic plans for their regions, they should consider the current condition of countries in the region, including their capabilities in education, technological research, capitalisation and infrastructure. This is especially true in considering emerging disruptive technologies such as nanotechnologies [31]. The condition of individual countries in the region forecasts the economic and social performance of the region.

Figure 1 Policy criteria diamond



6 Policies to promote regionalism

For regionalism to be successful in promoting Africa's nanofuture, possible policy approaches within that framework need to be considered. These policy alternatives can be implemented together. They include establishing collaboratory, leapfrogging, creating epistemic communities for informed policy making, and bridging the research-policy divide. Each of these approaches should be evaluated based on affordability, resource mobility, awareness, acceptability and sustainability.

Establishing a collaboratory to promote regionalism

The term 'collaboratory' was first coined from two words: 'collaborate' and 'laboratory' [32]. The term was defined by William Wulf in 1989, as a

> "centre without walls, in which a nation's researchers can perform their research without regard to physical location, interacting with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information in digital libraries." [33]

It was redefined to

> "a system which combines the interests of the scientific community at large with those of the computer science and engineering community to create integrated, tool-oriented computing and communication systems to support scientific collaboration." [34]

There are quite a number of other definitions that appear in the literature. Rosenberg in 1991 defined a collaboratory as

> "an experimental and empirical research environment in which scientists work and communicate with each other to design systems, participate in collaborative science, and conduct experiments to evaluate and improve systems." [34]

Cogburn in 2003 stated that

> "a collaboratory is more than an elaborate collection of information and communications technologies; it is a new networked organisational form that also includes social processes; collaboration techniques; formal and informal communication; and agreement on norms, principles, values, and rules." [35]

A collaboratory offers the platform where scarce instruments and data can be shared. It also improves interaction among researchers, and lessens the traditional barriers of status, time and space that impede scientific development [36]. This is important in promoting regionalism for Africa's nanofuture. Establishing a collaboratory as a policy approach meets the criteria of affordability, resource mobility, awareness and sustainability. In terms of acceptability, there are challenges; encouraging the creation of association among scientists is relatively easy, but building broader organisational structures is much more difficult, due to age-old traditions of scientific autonomy, formal organisational barriers and unwillingness to share implicit knowledge [37]. Shared spaces, which are normally created in most group practices and routines, pose the most significant barrier to the successful operation of collaboratories. The loss of a common physical setting as a result of establishing a collaboratory also poses a serious challenge to the normal process of collaboration and may weaken the effectiveness of the collaborative process by bringing new demands [38]. One of such new demands in the virtual environment is that employees must be explicit about information that under normal circumstances is tacit when co-located [36]. It is important to recognise that there will always be protection against widespread access to some specific scientific findings and data due to proprietary and economic considerations. To overcome these challenges embedded in virtual interaction, and to make collaboratory an effective policy tool to promote regionalism in Africa will mean a matter of highly structured designs and technologies that make virtual settings more like physical settings.

Scientific laboratories are physical settings designed to house equipment and scientists. "The forms of social organisation that grew out of this arrangement depended heavily on co-location" [36]. With advances in information technology and the unprecedented development of cyber infrastructure, collaboration without proximity became possible. Indeed, the goal of designing a collaboratory is to build "laboratories without walls or boundaries". This is a practical route to regionalism in Africa to advance an STI nanofuture.

The convergence of ICTs with traditional scientific practice resulted in the conceptualisation and development of collaboratories [39]. Collaboratories, by their nature, will not produce changes in science or necessarily promote nanotechnologies in Africa. However, they offer a new paradigm both for the practice of science and science policy making. The challenge is adoption and use of this approach. The scientific community, policy-makers in Africa and all those concerned with Africa's STI developments should actively explore how collaboratories can be used to improve Africa's participation in science.

The use of collaborative technologies to support scientific research in different jurisdictions and locations is gaining worldwide acceptance [38]. Collaboratories create the platform necessary for regional integration in important areas of S&T research and policy. Recent advances in S&T have been achieved through large multidisciplinary teams, as in the case of nanotechnology. The collaboratory is emerging as a viable tool in facilitating multidisciplinary approach to S&T research, using ICTs to lessen the constraints of time and distance. Collaboratories can, therefore, be an important policy tool for Africa's nanofuture through the promotion of regionalism. Alongside the opportunities offered by collaboratories is the challenge they present to human organisational practices [40].

Leapfrogging as a policy to promote regionalism

'Technology leapfrogging' is a concept that describes the practice of circumventing the stages in S&T developments gone through by others. It has been defined as

> "bypassing some of the processes of accumulation of human capabilities and fixed investment in order to narrow down the gaps in productivity and output that separate industrialised and developing countries." [41]

Leapfrogging takes into consideration the economic factors, existing technological climate, the power and larger socio-political interests in the existing and new technology systems, and a variety of other socio-economic implications, before the implementation of the new technology. However, the prospects are good for leapfrogging in the area of STI-NANO.

One misconception about leapfrogging is that technologically weak countries will bypass the countries leading the advances. Although there are potential circumstances in which the new technology may become more prominent in technologically weak countries than the developed economies, leapfrogging just means catching up by passing over some of the transitional phases of the technology [42]. The condition under which this may occur is that developed economies with broad legacy systems can have problems of inertia in changing over to new technology regimes. This is not likely to be the case for nanotechnology in general, in view of the way it is being implemented now. It may, however, be possible with specific nanotechnology applications. There are major differences in how technologies are implemented in developed and developing economies. New technologies are mostly deployed in a manner matching the existing infrastructure elements in developed economies whereas in less developed economies new technologies are mostly replacement of older technologies [43].

There are four key factors that need to be considered if leapfrogging can be used as a policy to promote regionalism for Africa's nanofuture. The first consideration is the nature of the new technology, i.e., how nanotechnology fits into the existing technology regime. Nanotechnology is described as a disruptive technology [44]. A technology is described as disruptive if it can change the production process of an existing product, and in so doing, generate a new or better-quality technology product paradigm [45]. Therefore, a disruptive technology makes the fundamental know-how linked with the old technology irrelevant and renders its technical infrastructure obsolete. Successful adoption and deployment of a disruptive technology becomes the supporting technology for a transformed industry. Other attributes of disruptive technologies include the facilitation of legacy infrastructure leapfrogging in emerging economies, redefinition of the fundamental competitive playing field for developed economics, and the creation of new platform for corporate have-nots to be successful [46].

Second, there are economic reasons for leapfrogging. Affordability and resource mobility are very important in this respect due to the generally scarce financial resources and foreign investments in Africa. This hinders the ability of most African countries to take advantage of the advances in emerging technologies and often had to rely on foreign investment, which their economies are not competitive enough to attract. On the demand side, potential users of nanotechnology and its products are not adequately resourced and thus create an uncertain market climate in most African countries.

Third, leapfrogging provides a way to deal with the power relations surrounding technology systems [41]. There is nowhere that new technologies are applied without building on/or coupled with existing systems; there cannot be a total green-field environment. The challenge of technology leapfrogging when various countries are involved is the vested interests in existing technology systems, which may act as barriers to the introduction of nanotechnology. Indeed, this can be a drawback to regionalism. Leapfrogging can be a way to jump-start change in power relations.

The fourth aspect of nanotechnology leapfrogging involves a wide array of other socio-economic factors. Important factors to be considered in any analysis of the potential for nanotechnology leapfrogging should include absorptive capacity and acceptability, technical infrastructure and know-how, complementary technologies like biotechnology and ICTs, and downstream requirements [41]. Absorptive capacity and acceptability involve the mechanics and systems of learning, adaptation and the willingness to use nanotechnology. Technical infrastructure and know-how deals with access to laboratory equipment and the environment in which nanotechnology can be transferred and used, including issues with intellectual property rights. Complementary technologies relate to the emergent nature of nanotechnology and the linkages with other related technologies being implemented. Downstream requirements deal with the creation of effective human-technology interface to manage the relations with the users [41].

Leapfrogging could help a region pursue nanotechnology. Regional leapfrogging can potentially have dual positive results. It offers the opportunity to remove the barriers that at present render individual countries as fairly closed STI entities. Second, the potential to commit African governments to nanotechnology programmes through the bandwagon effect, which has been very successful in Asia. Leapfrogging for Africa's nanofuture should be a continuous process and always strive for the cutting edge of the technology, for which some limited institutional capacity may have already been created. By leapfrogging in development of nanotechnologies, the regional blocs on the continent could provide a powerful climate for development in other sectors.

"Epistemic communities and informed policy making" to promote regionalism

Haas defined an 'epistemic community' as

> "a network of professionals with recognised expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within the same domain or issue area." [47]

Some commodity-dependent economies have moved from being mere exporters of raw commodities to become the designers, processors, manufacturers and exporters of value-added high-technology products as a result of otherwise bureaucratic establishments embedded with epistemic communities [20].

A country's ability to formulate and implement progressive policies is correlated with the level of expertise within that country. Availability of internal expertise makes it possible for policy-making bodies to acquire and process technical information that is needed for policy formulation. It is, therefore, important that Africa encourages the formation of epistemic communities, informal networks of professionals with renowned expertise and competence in nanotechnology and related fields, and with an authoritative claim to policy-relevant knowledge. In countries where policy-making is not driven by political correctness, epistemic communities are fully involved in all the different levels of the policy-making process, including the identification of policy alternatives, the choice of policies, and the formation of national and international coalitions to sustain those policies, whereas in politically motivated cases the policy-making process is largely controlled by politicians [20].

In considering policy alternatives and in every policy formulation process, there is some level of rationality; "if rationality is bounded, epistemic communities may be responsible for circumscribing the boundaries and delimiting the options" [47]. Although epistemic communities may be embedded in the bureaucracy, it is important to distinguish the two from each other. Whereas epistemic communities (depending on their normative objectives) use their expertise to formulate policies, bureaucratic bodies are more concerned about their mission and budget [20]. Again, although, in their operations, epistemic communities may use the bureaucratic leverage they gain as a result of their existence within a bureaucracy, they cannot be characterised as policy entrepreneurs [20]. Their modes of operation are different from that of people who are actually part of the bureaucracy. Members of epistemic communities are often involved in international policy dialogues and in national policy-making processes [48]. Africa can create epistemic communities from member countries to create the policy framework for its innovation nanofuture. Although in general there is lack of experts in the individual countries, there are experts scattered across the continent. Regionalism can bring these experts together to form epistemic communities for the regional blocs.

Bridging the research-policy divide as a policy to promote regionalism

One of the greatest challenges facing the continent of Africa is lack of use of research for evidence-based policy-making. This is made worse by the extensive lack of scientific capacity and poor public education in science and supporting disciplines. Attempts have been made to impose a 'foreign' paradigm of evidence-based policy-making without taking cognisance of cultural sensitivity, the nature of internal power structures, and indigenous and local knowledge systems [49]. This imposition has not been successful and therefore creates an intricate challenge for the science/policy interface that needs a system-wide study. However, despite these challenges, the demand for intermediaries to be involved in supporting the connections between science and policy have been very strong [50]. Intermediaries play three crucial roles in the science-policy linkages:

1 by acting as agents in bridging institutions and agencies in the absence of the required knowledge

2 by performing a liaison function for firms sourcing external know-how

3 by providing access to complementary assets for development of technologies internally [51].

Successful regionalism will require efficient knowledge interchange. Effective knowledge interchange can only be achieved through the midwifery of various types of intermediaries often working together. Active and multifaceted intermediation is very critical for the purposes of knowledge sharing and technology commercialisation, particularly when it is a tacit or uncodified knowledge [50].

There are opportunities for Africa's STI-nanofuture borne out of the willingness to engage, the quest for locally differentiated information, and crave for deliberation, involvement, views and advice [49]. These are also promising avenues for broadening science–policy interactions by getting more inputs from Africa into the global nanotechnology debate and dialogue. Although these avenues are important platforms for broadening science–policy interactions, due to the specific context of Africa in relation to cultural sensitivity, the nature of internal power and politics, and indigenous and local knowledge systems, there should be a strategic approach and with a high level of practicality [52]. Another challenge that faces Africa's nanofuture is the politicisation of science. Although science can be politicised anywhere around the globe, it is more pronounced in Africa due to poor level of education and non-existing infrastructure for evidence-based policy-making. One way to meet this challenge is to take advantage of mediation activities, which may prevent the politicisation of science. There is, however, the need for a systematic conceptualisation of mediation as there is no clear guidelines for the use of mediation in the literature [49]. It has also not gained the full acknowledgement as an important and practical public policy tool. It is, therefore, necessary for agents that hold themselves as intermediaries to unambiguously deal with the issue of mediation, and to investigate how levels of mutual credibility can be preserved through appropriate system of accountability and measures of decision-making [49]. Africa's STI-nanofuture will be brighter and the chances that nanotechnology can contribute effectively to poverty reduction will be enhanced if intermediaries are used to promote research for evidence-based policy-making.

7 Future directions

STI-NANO has been predicted to play an important role in addressing many of the challenges facing Africa in the areas of water, food and agriculture, nutrition, health, energy, and the environment for economic growth and poverty alleviation [21]. For a brighter STI-nanofuture and to benefit from the advances and innovations in global nanotechnology, African countries must pursue STI-NANO in the contexts of regionalism and international collaboration. They can no longer continue to approach science in isolated manner. There is the need for comprehensive regional integration in the approach to S&T developments.

It is in the interest of African countries to pool resources in terms of technical infrastructure, technical know-how and expertise together. Africa's input to global nanotechnology literature and patents is negligible. With probable exception of South Africa, most African countries lack the requisite research facilities and expertise in nanotechnology. This is because skill development and research facilities for an emerging technology like nanotechnology tend to be relatively expensive. Regionalism is the way forward if African countries are to garner resources to acquire these facilities. To employ and benefit from advances in STI-NANO and facilities located elsewhere, Africa needs world-class researchers with the set of skills that will provide the platform for effective analysis and action in scientific, technological and environmental policy and enable them to understand the increasingly complex issues that straddle international and national development and who can communicate and collaborate with the best scientists around the world on international nanotechnology projects [1]. This challenge is not lost on African policy-makers and scientists as they acknowledge the essence of regional cooperation in S&T. The importance of regional integration and cooperation is clearly stipulated in most regional and sub-regional treaties and in minutes of meetings, and articulated in various policy statements [1]. However, all these stipulations and articulations remain statements of intents and little has been done to implement them. Many African countries with limited expertise and financial resources are developing their national innovation systems and S&T policy in isolated fashion and thus spreading the limited resources of the continent too thin across various fields. Moreover, some of the countries with relatively 'good' existing S&T infrastructure are not accessible to others in the region due to various socio-economic and political factors.

Failure at institutionalising S&T programmes in the regional economic communities (RECs) has been described as one of the main reasons why past attempts to use regionalism for technology development have not been successful in Africa [1]. Most of these regional blocs lack the requisite capacity in policy implementation. There is a need to establish science portfolios in each of the RECs, to ensure that regionalism advances S&T.

Regional leadership is an important factor in technological innovation and development and establishing this STI culture requires political leadership [1]. Investments in technology have many benefits including improving good governance of African economics and related politics. Nanotechnology maybe key to increasing the continent's economic productivity and political stability as it has been projected to affect commodity-dependent economies in various ways. In addition to making statements of intents, African leaders need to put more emphasis on how to implement these policies for national and regional development. At present, Africa is lacking such political leadership focused on integrating technology concerns into economic and social strategies.

8 Conclusion

Africa faces an uphill battle with regard to the adoption and use of nanotechnologies. The strong potential to improve the livelihood of resource-poor Africans is a strong incentive to meet the challenge. However, this incentive will not become a capital if it is perceived as simply a cynical strategy or ploy to gain support for the technology, or if it becomes another vain hope. The policy options available to Africa are varied.

Policies should outline priority areas in nanotechnology that are of relevance to Africa's development. They should identify critical capabilities needed for the development and safe use of nanotechnology and establish appropriate regulatory measures that can advance research, commercialisation and trade and consumer protection. Policy should also set strategic options for creating and building regional nanotechnology innovation communities and local innovation areas in Africa. Africa's nanofuture lies in harnessing the power of regionalism as an overarching policy framework.

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