Nanotechnology in South Africa – Challenges in evaluating the impact on development

AUTHORS:
Trust Saidi[1]
Tania S. Douglas[1]

AFFILIATION:
[1]Division of Biomedical Engineering, University of Cape Town, Cape Town, South Africa

CORRESPONDENCE TO:
Trust Saidi

EMAIL:
trust.saidi@uct.ac.za

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Nanotechnology has captured global attention as the technological platform of the next industrial revolution.[1] South Africa is one of the few countries from the global South that have adopted nanotechnology with the aim of enhancing global competitiveness and sustainable economic growth. As early as 2005, South Africa displayed an interest in nanotechnology by publishing and subsequently implementing the nanotechnology strategy and an associated 10-year plan.[2] The strategy explicitly outlined the country's niche areas in the application of nanotechnology, namely water, energy, health care, chemical- and bio-processing, mining and minerals, and advanced materials and manufacturing.[3] The applications focused specifically on areas that were expected to benefit the country, as the overall goal was to support development. About 10 years have elapsed since the strategy was implemented and the question has inevitably arisen as to how the technology has contributed to the development of the country. We argue that it is not easy to measure the impact of nanotechnology on development.

South Africa's nanotechnology strategy

The South African National Nanotechnology Strategy focuses on four priority areas of intervention: the establishment of characterisation centres (national multi-user facilities), the creation of research and innovation networks (to enhance interdisciplinary, national and international collaboration), the building of human capacity, and the establishment of flagship projects (to demonstrate the benefits of nanotechnology).[4] These interventions are meant to facilitate the realisation of the country's vision of economic growth, poverty reduction and enhancing quality of life. The strategy identifies two development clusters – industrial and social.[3] The former targets mining, minerals, chemical- and bio-processing, and materials and manufacturing, while the latter focuses on the provision of clean and purified water, affordable and renewable energy, and improved primary health care.

Since the implementation of the strategy, South Africa has established two national nanotechnology innovation centres – at the Council for Scientific and Industrial Research (CSIR) and at MINTEK.[5] These centres collaborate with other national institutions in the design and modelling of novel nanostructured materials as well as in the application of nanotechnologies in the fields of water, health, mining and minerals.[2] In addition, Centres of Excellence are spread across universities in South Africa. The country has created research and innovation networks, both nationally and internationally, to enhance collaboration in nanotechnology. For example, the India–Brazil–South Africa (IBSA) project provides a platform for collaborative research in nanotechnology among scientists and organisations from these countries.[6]

In terms of human capacity development, South Africa is actively engaged in building a critical mass of graduates skilled in nanoscience and nanotechnology. A dedicated postgraduate programme has been introduced, with four South African universities collaboratively presenting a master's degree.[7] Furthermore, the country has set up flagship projects on the application of nanotechnology in water, energy, health, chemical- and bio-processing, mining and minerals and advanced materials and manufacturing. The investment in the flagship projects has yielded considerable outputs; for example, by 2015, 464 postgraduate students had been trained, 92 postdoctoral fellows supported, 326 collaborations established, 352 articles published in highly cited journals, 80 conference proceedings recorded and 17 patents registered.[8]

Thus, the strategy's priority areas of intervention – projects, facilities, networks and training – have produced outputs. The impact of these outputs, however, remains to be assessed. The industrial cluster identified in the strategy has shown some development in that the synthesis of known and novel biomaterials has benefited the advanced manufacturing technology sector.[7] Impacts on other aspects of the industrial cluster and on the social cluster are more elusive. Conventional ways of assessing the impacts of a technology are less effective when applied to nanotechnology. For example, the traditional methods of cost–benefit analysis, life-cycle assessment, constructive technology assessment and real-time technology assessment are versatile tools for evaluating the impacts of a technology along the entire product value chain.[9,10] However, nanotechnology has unique attributes, and despite the progress made so far in implementing the nanotechnology strategy in South Africa, it is difficult to determine the impact of the technology on development.

Challenges in assessing the impact of nanotechnology on development

Nanotechnology has been characterised as a general-purpose technology.[11] It is pervasive and has a propensity to spur complementary innovations that cut across many technological sectors.[12] Nanotechnology is becoming integral to many modern-day products, as a part of either the product or the manufacturing process, yet not always in a recognisable manner. The applicability of nanotechnology in virtually all manufacturing sectors means that its impacts become larger and harder to predict and measure. Nanotechnology is indeed being used widely by industries in South Africa, particularly in catalysis. The multi-purpose and enabling nature of nanotechnology makes it difficult to measure its impact using tools such as life-cycle assessment because the technology can be part of a product's key functionality, or just ancillary to the value chain and representing a small portion of the final product or process.

A second challenge is that nanotechnology is a misnomer as it is not just one, but multiple, technologies that involve manipulation of matter at the nanoscale. Sparrow[13] argues that we should be talking about 'nanotechnologies' instead of nanotechnology, as the technology is a microcosm of the whole innovation ecosystem. For example, the value chain of nanotechnology is incredibly long as it stretches from nanomaterials to nano intermediates to nano-enabled products.

Many different nanotechnologies have emerged, are emerging or are likely to emerge and it is hard to define where the technologies start or end. Thus having an umbrella term for technologies that have little in common other than the scale of the structures they produce or manipulate, makes it cumbersome to assess their impacts. The impacts of nanotechnology are often intermingled with that of many other interventions and technologies. This is further complicated by the fact that nanotechnology integrates multiple and overlapping scientific disciplines. As nanotechnology is not a discrete technology, it is difficult to use cost–benefit analysis and real-time technology assessment to establish its impacts.

Thirdly, nanotechnology embodies the three forms of a technology as defined by Wajcman[14], as (1) sets of physical objects or artefacts, (2) human activities such as designing, making and handling of machines and (3) knowledge. Approaching nanotechnology using the lens of these layers means that when evaluating the impact of the technology, the focus should not be limited only to physical objects. Instead, it is important to incorporate the manufacturing processes as well as the knowledge generated. This inclusivity is challenging, as the latter forms of the technology tend to be invisible to ordinary consumers. While many forms of modern technology are invisible in that users generally do not know how they are produced, this phenomenon is likely to be more pronounced in relation to nanotechnology, thereby making the measurement of its impact by conventional methods problematic.

The futuristic cladding of nanotechnology is a fourth challenge, as it disguises the temporal aspect of the technology. For instance, the South African Nanotechnology Strategy stipulates the expected outcomes of the technology, but it is difficult to predict with certainty when an emerging technology will deliver. When the strategy was implemented, it was expected that by 2014, the projects would have matured and reached a stage of self-sustenance by generating their own income. However, by 2014, many projects were not ready to stand on their own, as their products were not yet fit for commercialisation. What is explicit from this is that nanotechnology is driven by future-oriented claims, which tend to enforce the legitimacy of the emerging technological sphere. The expectations of nanotechnology on the one hand and the realisation of its applications on the other, denote a problem of temporality as a result of discrepancies between time horizons. Constructive technology assessment, which is often used with emerging technologies, is less useful in this case because of a lack of clarity about when products might reach the market.

The final challenge of measuring the impact of nanotechnology on development emanates from the fact that the technology is characterised by complex and heterogeneous cycles of hope, expectation, hype and disappointment.[15] For instance, during the period when the South African Nanotechnology Strategy was published in 2005, 'nano' was a buzz-word, and one could easily be tempted to add nano as prefix to a product or service to make it fashionable. It is not surprising that even products that did not embody nanotechnology per se could use the label strategically for marketing purposes. It was not until the unknown risks and uncertainties of the technology were raised that some nano-enabled products started to drop the label. As the discourse on nanotechnology increasingly includes concerns about its safety, products containing nanotechnology may no longer necessarily stand out, or be advertised.[12] Such a situation makes it problematic to identify applications of nanotechnology because unless a product is labelled as containing the technology, it is difficult to ascertain whether it does or does not. Thus, the fallout from overhyping nanotechnology brings complications such as failing to identify nanoproducts on the market, which poses further challenges in measuring its impact using conventional methods.

Thus, the generic but also heterogeneous nature of nanotechnology, its different technological manifestations, its status as an emerging area in South Africa, and the impact of its changing perceptions in the public mind, challenge the assessment of its developmental impact in South Africa. These challenges render conventional methods of technology assessment less effective. The unusual character of nanotechnology calls for unconventional and pluralistic approaches for the analysis of its impact on development.

The way forward

Although the impacts of nanotechnology are difficult to measure, that does not necessarily mean that the technology is not contributing to the development of the country. The challenges in assessing the impact of nanotechnology are compounded by the complexity of forces that drive economic growth and the long timescales from research-based discovery to commercialisation of technologies, often 20 years or more. However, such a disposition should not be used as an excuse for postponing investments in nanotechnology as it may result in South Africa missing opportunities for development. Instead there is need to devise mechanisms for measuring the impact of nanotechnology on development. This measurement may entail evaluating the economic impacts of investments in nanotechnology research and development in a rigorous fashion using a set of metrics and an aggregation of data on technology transfer and commercialisation.

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