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Global Challenges in Science and Innovation for Sustainable Development: Remarks from a Cuban Perspective

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During the Twentieth Century, science and technology underwent spectacular progress. It was the century of the *Quantum Revolution* that led to impressive advances in numerous knowledge areas, in engineering, and to an endless number of key inventions, all of them crucial in developing our knowledge of the planet, its ecosystems, the human body and space exploration. It was also the Century of the *Bio-Molecular Revolution,* which, starting from DNA molecule decoding, and from the development of genetic material's enzymatic manipulation in living organisms, permitted biology to move, in barely 120 years from the rediscovery of the Mendel Laws in 1900 to identifying huge parts of the Human Genome today. The third great moment of the 21st Century was the *Informatics Revolution*: with the invention of the transistor, it allowed the subsequent development of microelectronics, the modern computer, and the Internet, all of which have been important factors in contemporary achievements in Information and Communications Technologies (ICTs).

There were also other discoveries in that century that deserve to be mentioned: aviation and nuclear energy, the beginning of space exploration and understanding of celestial processes; genetic-molecular study in the evolution of the species and *the influence of their habitat*; the 'green' revolution and greater precision in agriculture; the theory of Tectonic Plates and Continental Drift, which shocked from its very beginning; Earth Sciences; the considerable development in complex systems' studies, remarkable applications of which are the behavior of atmospheric processes, the climate, and the biodiversity.

However, in a century where 90 per cent of history's scientists and engineers lived, it would be impossible to mention all of the discoveries, advances, and valued knowledge. It is undeniable that all of those mentioned above not only transformed our thinking, knowledge and the nature of understanding, but they have also had great impact in industry, economy and contemporary society. Yet in parallel it should be noted that advances in science and technology have been widely used for military purposes. There also exist important environmental and safety issues, that raise a series of wider concerns, such as: the need to harmonize economic development with global warming; the need to confront depletion of natural resources, pollution of waters, the atmosphere and the soil; the loss of biodiversity; the increase of desertification and natural disasters, etc.; as well as the need to grant internet users privacy and to assess ethical factors relating to cloning technology. International efforts to address these problems are needed now more than ever.

TWENTY-FIRST CENTURY CHALLENGES

Indeed, this century will be critical for the future of humanity. In addition to the problems described above, other challenges include: the supply of water; food and energy security; the problems of population aging; poverty; public health; the increase of chronic and non-communicable diseases; and the sustainable management of large cities. All of them are linked to the several global crises that prevail and influence each other, meaning the economic and financial crises, as well as global population growth. At the same time, the benefits of scientific and technical advances have not been equally distributed at a planetary scale and do not reach the majority of the population.

Something that constitutes irrefutable evidence of unequal development and the current existential gap between societies is the fact that of the million patents and more than two million scientific articles published in the world each year, 90 per cent of the former and 85 per cent of the latter come from d**e**veloped countries. In addition, at the end of the 2012, of the 2.405 billion Internet users worldwide, 77 per cent are from Europe, North America and Asia. Besides, in the last few years, the fields where knowledge plays a critical role - electronics, computing, software development, telecommunications, biotechnology, nanotechnology, aerospace, high technology for healthcare, new materials, polymers and plastics, pharmaceutical, chemical products, etc. - have expanded mainly in the industrialized countries.

Regarding education challenges, there are three pressing issues that should be taken in consideration of global development: first, the eradication of existing and unacceptably high levels of illiteracy; second, the need to promote high-quality universities in order to obtain the critical mass of scientists and engineers, as well as others who are capable of addressing the new productive high-technology systems; and third, the need to increase the general scientific-technological culture of the population. In relation to the euphemistically so-called 'brain circulation' – which is, in fact, a brain drain - in recent years in the underdeveloped countries, 1.3 million out of almost 7 million people with high professional qualifications have emigrated.

It is predicted that, by 2050, there will be 9 billion people residing on the planet. This will demand radical terms of social justice, political stability, as well as they energy, health and food security that presently around 900 million hungry people in the world do not have.

CAN SCIENCE FEED THE WORLD?

The first question that arises in this context is whether or not science can, indeed, feed the world. As experts have pointed out in different international meetings, in order to achieve this purpose, from now until 2050 we need to produce the same amount of food that mankind has consumed in its entire history. This implies a production increase of 70 per cent on current rates of productivity, and to incorporate into agriculture a land area corresponding to the whole of Brazil, something which is obviously not possible. Important improvements in agricultural practices have been introduced, and now genetic modification offers the possibility to obtain plant varieties which are resident to drought and offer greater productivity. Moreover, satellite images enable precision agriculture and are also useful to classify, control and manage land use in order to launch early alert campaigns where they are needed. However, these improvements are still unable to power the 'new green revolution' that is essential to satisfy growing human requirements. The sustainable expansion of global agriculture could only be achieved through the assimilation of technologies that will require a better understanding of some fundamental biological processes and new technologies yet to be developed: not only for the efficient use of solar energy in photo-synthesis; but also to control the inverse process. It means the use of green mass to produce energy, which will require more efficient technologies to capture the chemical energy comprised in cellulose and other vegetable polymers. The current controversy on biofuels is making it clear, among other things, that there do not yet exist efficient technologies for this purpose.

In terms of energy production, there is consensus that the end of the useful life of fossil fuels is in sight, though new discoveries of reserves at the bottom of the oceans, could permit their continued exploitation for a while yet, particularly if appropriate and viable extraction technology becomes available. In addition to that, for industrial energy, the alternative sources that are developing require an augmentation of our knowledge of certain physical processes and basic engineering for their full deployment. None of the most promising alternatives - even if the realization of nuclear fusion, something which has a long way to go, occurs - or updated renewable energy sources by themselves will be able to replace fossil fuels. The solution, that will only have considerable implications in a middle term, will have to be a holistic approach based upon a combination of energy sources and technologies, and an improvement in the efficiency of industrial processes.

Global health will be also affected in a more heavily populated planet. In addition to well-known pandemics, a more frequent threat will be new viruses which are the product of recombination between human and animal strains, and antibiotic-resistant bacteria, along with deadly pathogens, which, in the recent past, were confined to small populations, but can now spread all over the planet in the space of days or weeks. For the rapid development and deployment of new vaccines, antibiotics and diagnostic techniques, new knowledge, technologies and therapeutic approaches will be necessary.

SCIENCE, TECHNOLOGY AND DEVELOPMENT

An important consideration relates to the role of progress in science and technology in accelerating social, economic and human sustainable development.

Since the turn of the Millennium, major changes have occurred in science and previously unimagined dimensions of knowledge and technology have been reached. It should be considered that the main driving forces of science, at its most fundamental level, have always been passion, curiosity and fascination, and the essential feature of modern science is the synergy between its pure and applied dimensions. The multidisciplinary nature of much cutting-edge science, and the way in which advances in new fields have interlaced and overlapped with each other is evident in the so-called enabling technologies. Furthermore, the current trend is also to establish research with different multidisciplinary goals and technological platforms which are able to adapt better to continuous change, and to boost the convergence among technologies from diverse enabling fields; for example, the so-called Nano-Bio-Info-Cogno (NBIC) which shows the root link between contemporary science and high technologies, and the way fundamental knowledge and discoveries in different branches of science transform very rapidly into new products and industries.

Another issue that is always present is the impact that basic science and theoretical research can have in engendering progress in the economy. Let us take for example in 1850, the response of Michael Faraday to the then British Minister of Finance on the practical use of electricity: 'Sir, one day you may tax it'. Although currently there are no unique tools, or advanced scientific methods to accurately measure the contribution of innovation and new technologies to economic development, numerous studies indicate that science has been the main source of the rapid economic development of the last 150 years, intensified after the 1970s and the creation of the so-called knowledge-based economy. In the field of physics, a good example is quantum mechanics, which developed rapidly during the 1920s, away from any application, and has led to many subsequent discoveries and core applications of modern life. It is estimated that, in the United States, 30 per cent of GDP is based on inventions that have been made possible by quantum mechanics, from semiconductors in computer chips, up to the laser equipment of DVD, magnetic resonance imaging in hospitals, mobile telephony and much more.

Progress in other key areas of modern biology, chemistry, and mathematics, as well as their interdisciplinary connections applied to earth sciences, agriculture, engineering - even those that study society - have shown the effect of new ideas and technologies, as well as on economic growth.

With regard to the prospects for innovation and application of discoveries that will change the world in the 21st Century, scholars at the Massachusetts Institute of Technology (MIT) have identified ten key technologies. To maintain and increase competitiveness, attention has been paid to: advanced materials; mechatronics; the soft/hard constraints for Grid systems; aerospace, and armament industries; vehicle production; micro- and nano-electronics; and human health applications, in particular bio-technology and nano-technology, to which more than 50 per cent of global resources are today devoted.

However, as for successful experiences in selected developing countries, as the example of Cuba shows, the realization of this potential depends on a group of policy instruments aimed to convert scientific discoveries into goods and services.

CONCLUDING THOUGHTS

In concluding, let me briefly refer to certain aspects of the development of science and innovation in Cuba.

Since the dawn of the revolutionary triumph, the country's historic leader defined the importance of scientists and intellectual production for the future of the country. In this regard, fifty-five years of consistent state policy has led to notable success in the fields of education and science, acquiring in recent times a valuable scientific potential of 0.95 per 1000 inhabitants. This has also afforded the creation of a proper scientific and technical infrastructure. Last but not least, Cuba has achieved a high level of public health, something that is well-known and illustrated with the following data: there are six medical doctors per 1000 inhabitants, equally distributed through the country; life expectancy is currently 77.9 years; and Cuba exhibits an infant mortality of less than five per one thousand births.

Since the 6th Party Congress in April 2011 and the consequent approval of 313 guidelines for economic and social policy development in the framework of its socio-economic model, a future space for science and technology is granted, and constitutes one of the fundamental factors of economic and social development of Cuba.

What role can and should Science and Innovation play today? In a small country lacking major energy resources and a demographic prone to aging and a low birthrate, it is crucial to sustain and develop: basic and natural sciences; renewable energy sources; the biotechnology and pharmaceutical industry; the production of advanced equipment in health sector; scientific and technological services of high added value; and the systematic assimilation of emerging technologies.

Similarly, a restructured National Scientific and Innovation System must be able to: provide modern procedures of management and scientific policy; maintain scientific potential via high levels of training of its researchers; support basic and natural sciences; set up a competitive system of financing, that serves as a stimulus to the talent and creativity; and at the same time manage to reverse the demographic aging of scientists as well as the deterioration and obsolescence of equipment and laboratories.

In places where the necessary conditions exist, it is convenient to promote the transformation of research institutes into high-tech companies. A good example is the approved merger of the West Havana Scientific Cluster, and the pharmaceutical industry into an enterprise holding named 'BioCubaFarma'; a merger which has allowed the transformation of these industries into a new buoyant sector of the economy based on knowledge that will boost the transfer of technology and lead to the expansion of the country's access to international markets, including those in developed countries. It will also bring practical benefits in the creation of new health services facilities, with higher productivity and quality standards, using top qualified workers, as well as producing new generation drugs and increasing the pharmaceutical portfolio.

Which role may a new emerging technology - such as nano-technology - play in the context of these profound transformations? The Cuban biotechnology industry matured and was consolidated in around a quarter of a century, under complex conditions of economic crisis, financial strains and external pressures. It is expected therefore that, together with the current creation of a new Center of Advanced Sciences dedicated to this subject, the intensive research and innovation activities in universities, and new business niches, nano-sciences and nano-technologies will also become a strategic axis of development in the country. I am not referring to the immediate future, but to the efforts that should be taken and to the vision of creating today the necessary scientific, technical and productive infrastructure capable of achieving the above-mentioned goal.

Current shifts, including the recently passed foreign investment law, also allow the creation of innovation centers and scientific parks; organizations able to bring together, with the demand for new products and the commercialization, academia and the business world. This also facilitates the emergence of derived companies such as start-ups and spin-offs.

In concluding, I would like to share with you the following thought of Louis Pasteur, expressed 150 years ago:

> Science is the soul of the prosperity of Nations and the living source of all progress.

I am convinced that this phrase could have been pronounced nowadays because, on the one hand, the future of the mankind will depend on its present ability to develop an economy that is not only efficient in the use of resources, but also socially inclusive. On the other hand, the creation of new knowledge and technological changes occurs at such a pace that we can remain permanently excluded if we do not have enough wisdom to understand, preserve and increase them, and the due tenacity to carry them out.

NOTES ON CONTRIBUTOR

Fidel Castro Díaz-Balart is the Scientific Advisor of the State Council, Republic of Cuba, a position he has held since 2003. Prior to this position he has held a number of important roles in Cuba, including Chief of Scientific and Technological Activities in the Cuban Ministry of Basic Industry, the Executive Secretariat of Nuclear Matters, and Executive Secretary of the Atomic Energy Commission of Cuba. He obtained his MSc (Hons) in Nuclear Physics from M. V. Lomonosov State University, Moscow, in 1974. He earned his PhD in Physical-Mathematical Sciences in the I. V. Kurchatov Atomic Energy Institute in Moscow. He also obtained a MSc. equivalent degree in Strategic Planning and Higher Management from the Russian Council of Minister Management Institute in Moscow, and obtained a MSc. degree in Project Management from the School of Industrial Organization (EOI), Madrid, Spain. In 2000, he obtained a Doctor of Sciences degree from the Higher Institute for Nuclear Sciences and

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