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Romain Murenzi

Executive Director,

TWAS, the academy of sciences for the developing world

Trieste, Italy

The news out of Africa is brighter than it has been in a long time.

Over the past eight years, the annual growth of the gross domestic product (GDP) in Africa has averaged 7.6%. Moreover, in a recent report, the International Monetary Fund (IMF) noted that the economic downturn on the continent, due to the global financial crisis that began in 2008, was "mercifully brief."

Indeed, in Africa, success is no longer being defined by avoiding the worst. According to *The Economist*, several of the fastest growing national economies are now in Africa, including Angola (12.8%), Sudan (12.8%), Equatorial Guinea (12.7%) and Ethiopia (9.8%), each of which has experienced rates of economic growth that rival that of China and India.

Democracy is also on the march, according to *The Economist Intelligent Unit*. A growing number of African countries currently enjoy some degree of democracy, including Mauritius, Cape Verde, Botswana, Rwanda, Namibia, Benin, Guyana, Lesotho, Ghana and Mali.

And foreign direct investment (FDI) in Africa has increased by more than 80% during the past decade. In 2003, China invested USD748 million in Africa; in 2009, it invested USD9 billion. Yet China still contributed only 2% of FDI on the continent, compared to 36% each for the USA and EU. Globally, in 2001, Africa received a total of USD13.8 billion in foreign direct investment. In 2008, it received USD200 billion. That figure has since declined sharply in the face of the global economic downturn.

Yet, when it comes to science, technology and particularly innovation (STI), the prospects dim considerably. Africa, which is home to 15% of the world's population, has less than 3% of all researchers. African scientists publish less than 2% of the articles in peer-reviewed international journals. Africa technologists file less than one-tenth of 1% of the applications received by the US Patent Office.

Although recent economic trends in Africa are encouraging and undoubtedly are welcomed, the truth is that the continent has yet to build a strong foundation for science-based sustainable development.

This should be a source of deep concern because the future of Africa depends, in large measure, on sustained investments in STI.

Development in today's world goes hand-in-hand with STI. The quality of STI within a country, in turn, depends on a well-educated workforce and an entrepreneurial environment that encourages and rewards risk taking.

A country's economy, of course, can be spurred by commodity production and the short-term advantages afforded by low-cost labour. But there is no substitute for having a strong framework for STI designed to support efforts to propel sustainable economic development in the 21st century.

STI is not only essential for the creation of jobs and wealth, but also serves as a powerful tool for combating such critical challenges as food and energy security, access to safe drinking water, climate change and the spread of infectious diseases.

In short, we live in a global economy that is fuelled, to a large extent by STI – a factor that holds true for both developed and developing countries.

Emerging economies such as Brazil, China, India, Malaysia and South Africa have turned to STI as a cornerstone of their economic development strategies, and their recent success has served as model for others. Yet, many other developing countries continue to struggle in their efforts to make STI a central feature of their efforts to reduce poverty and grow their economies. In fact, TWAS, the academy of sciences for the developing world, has identified 80 countries that continue to lag behind in STI capacity building. More than half of these countries are in Africa. Not surprisingly, Africa is the only continent that is struggling to meet any of the Millennium Development Goals (MDG).

Recent history shows that we simply cannot afford to repeat the mistakes of the closing decades of the 20th century when the prevailing attitude was this: STI may be nice for developing countries to pursue, but other challenges are more pressing. The fact is that science is essential for the well-being of all countries – now more than ever.

Stepping forward

Three major steps will have to be taken over the next several decades if countries currently stymied by lagging scientific and economic capacity are to join both the international scientific community and the global economy as full and equal partners.

First, there is an urgent need to provide adequate training – in terms of both quality and numbers – for the next generation of scientists seeking doctorate degrees.

Without the presence of a critical mass of professors with PhDs, and in the absence of doctorate-level research, there is no way that scientific capacity can be built – let alone flourish – in poor countries.

Second, steps must be taken to expand opportunities for scientific exchange for scientists in poor countries with their colleagues in scientifically and technological advanced countries.

There are a growing number of fellowship opportunities available for scientists from developing countries both through bilateral and multilateral frameworks. Yet the total number of openings remains small. As a result, too many eager and able young scientists in developing countries continue to be denied opportunities to obtain advanced degrees.

Third, scientists (particularly young scientists) from developing countries must have broader opportunities to obtain merit-based research funds to continue their studies.

Again, levels of funding are increasing but not rapidly enough to meet the growing demand. Part of this funding can be derived from foreign donors but part must come from the countries themselves.

Making Innovation Happen

Innovation is derived from many sources. Indeed a growing number of scholars and analysts have suggested that innovation is not a “single thing” but, in reality, is an “integrated system” that cannot be imposed from the outside, but that must grow within the borders of each country.

The system involves several factors including: good governance with leaders that place a high value on excellence; an educational system that cultivates not only knowledge but imagination and initiative; an infrastructure that extends beyond roads and bridges to broadband internet and web portals, and a social framework that rewards risks and doesn't unduly penalize failure.

While certainly not the only element, science is a critical component of the system. Science, as part of a larger system for STI, serves as a continual source of material progress as shown, for example, by the positive impacts that information and communication technologies (ICTs) and advances in medical diagnosis and treatment have had on social and economic well-being.

But what is often less well appreciated is that science, by virtue of its unwavering dedication to transparency and excellence, also reinforces principles that drive STI forward and enable it to be embraced as a cornerstone of economic and social progress.

This is one of the major reasons why a system of STI cannot simply be imported from elsewhere but must be developed indigenously. The lessons of the past several decades, as reflected in the experiences of Brazil, China, India and other emerging economies, are clear for all developing countries: Successful applications of STI depend on it being fully integrated into the society in which it is being applied. In particular, science for the sake of science may be a universal endeavour. But science for the sake of development is very much a national pursuit. As a result, the environment for such efforts, in short, must be grown at home.

The Case of Rwanda

The experience of my home country in Rwanda shows how STI can become rooted in the national experience done, and that the experience does not have to take decades to take hold.

In 2000, Rwanda had just emerged from years of civil war that had left one million people dead. It was upon the smouldering ashes of genocide that Rwanda, under the leadership of President Paul Kagame, decided to launch a long-term, comprehensive programme for science-based development.

At the time, Rwanda was among the poorest and most densely populated countries in Africa. It was also one of the most dysfunctional countries in the world – a failed state by almost any definition.

Moreover, it was a landlocked country with few natural resources. Rwanda's recent past, in short, was dismal and its future in the aftermath of a decade of intense violence and unspeakable destruction didn't look much brighter.

By the criteria established by the international financial and development communities in the last half of the 20th century, this would have been no time to turn to science and

technology. Science and technology during this period were largely viewed as “luxuries” that countries, such as Rwanda, could not afford to develop on their own. It would be better, the argument went, for poor countries to devote their meagre resources to other, more immediate concerns and to buy the science and technology from other countries that had the wealth to invest in such endeavours. As for innovation, if it was discussed at all, the conclusion was that these countries had neither the skills nor the need to engage in such pursuits.

But by the time Rwanda began to climb out of the deep hole of despair, perceptions towards development among both policy experts and public officials had begun to change.

First, there were growing concerns about the effectiveness of the so-called “Washington Consensus,” which called upon countries to get their fiscal house in order first, even if this meant significant cutbacks in public expenditures for such vital matters as infrastructure, education and research.

Second, there was the growing success of China and an increasing number of developing countries, which not only created alternative pathways to economic success but also showcased the importance of developing indigenous capacity in STI.

And third, the rise of such global challenges as climate change, food and energy security, biodiversity loss and public health strongly indicated that a world which had become increasingly globalized could not hope to enjoy continual prosperity and security if large numbers of countries were left behind. Building scientific capacity in poor countries, the new arguments went, should not just be a matter of concern for scientifically lagging countries but for the entire world.

A direct corollary to this notion is that no nation can address its critical social needs and create secure, well-paying jobs for its citizens without helping them to acquire the skills that they need to prosper in a highly competitive world. In the 21st century, this means two things above all others: first, providing all citizens with an excellent education and, second, building indigenous capacity in STI to ensure that excellent and rewarding career opportunities exist for a country’s “best and brightest.”

These are critical challenges for a country like Rwanda, a small landlocked nation with just 10 million people and few natural resources. Nearly 90 percent of its population are subsistence farmers.

Rwanda’s government now spends 1.6%?? of its GDP on S&T. By 2012, it hopes to increase this level to 3%, which would be comparable to the highest levels of investment on S&T in developed countries.

Rwanda is admittedly working from a small economic base. The per capita gross domestic product (GDP) in 2007 was just US\$365. But it is important to bear in mind that the country's economy is growing rapidly. In 2002, for example, per capita GDP was just US\$202.

One of the most significant aspects of Rwanda’s success lies in improvements to its educational system. Over the past decade, student enrolment in primary education has doubled from 940,000 to more than 2 million; enrolment in secondary education has increased seven-fold from 50,000 to roughly 350,000; and in higher education, it has risen more than 10-fold, from 3,000 to over 40,000.

In Rwanda, STI are at the centre of the nation's reform efforts in higher education. Not only is the country building centres of scientific excellence (for example, the Kigali Institute of Science and Technology [KIST]), but it is also setting aside 70% of all government student loans for university students majoring in STI-related disciplines.

In addition, the government is investing in a broad range of projects to improve the nation's technological capabilities. For example, with financial assistance from the World Bank, Rwanda has built a state-of-the-art technical school, *Ecole Technique Officielle* (ETO) in Gitarama. The goal is to provide students with world-class technical skills that are coveted by both industry and academia. Since the programme's inception nearly a decade ago, several hundred students have earned technical certificates from ETO. In partnership with the Rwanda Workforce Development Authority (RWDA), a number of ETO graduates are participating in one-year industrial work study placement schemes to further hone their skills in a business environment.

At the same time, the government has focused on promoting "demand-driven" research designed to address such critical societal challenges as the need to increase agricultural productivity (focusing on science-tested ways to boost yields of wheat, rice, maize and other diet staples) and to protect the environment (by strengthening the research base to enhance forest and soil conservation).

Perhaps most significantly, Rwanda is keen to expand its nascent system of innovation. This will require not only enhancing the country's educational and research systems, but also nurturing entrepreneurial skills of its people by encouraging the commercialization of knowledge-based products and services and by protecting intellectual rights (IPRs). The creation of effective and enforceable laws and regulations to cultivate an environment of innovation and secure IPRs are critical aspects of its overall strategy. So, too, is the creation of technology incubators and parks, as well as innovative centres, which can serve as a bridge between universities and the private sector.

Rwanda harbours aspirations to become one of Africa's major knowledge and high-technology hubs and, equally important, to emerge as a middle-income country by 2020. But the government believes that the process by which the country seeks to achieve these goals is just as important as attaining the goal itself.

Indeed the government fervently believes that the policy process is inseparable from the policy outcome. Top-level government commitment, backed by adequate resources, is essential for realizing Rwanda's dreams. The government, moreover, believes that Rwanda's experience could help guide the policies of other countries on the continent – or at least serve as a valuable example of a successful comprehensive strategy for science-based sustainable development from which others can learn lessons.

As President Kagame has stated, "Africa must either begin to build its scientific and training capabilities or it will remain an impoverished appendage to the global economy." In addition, President Kagame has called on governments across Africa to apply "science and technology holistically – to promote education and training; to commercialize ideas, develop businesses and quicken the pace of wealth-creation and employment generation; and the provide the basic tools to society for both self and collective betterment."

Rwanda may not be able to replicate the success of countries like Singapore. But the government believes that Singapore has a great deal to teach other small countries with limited resources, especially when it comes to devising effective policies for science-

based development. Equally important, Rwanda's political leaders have come to believe that setting expectations too low (an attitude towards poor countries that shaped the opinions and policies of developed countries in the closing decades of the 20th century) poses a far greater risk than setting expectations too high.

2020 Vision

The *Rwanda Vision 2020* report, which calls for Rwanda to become a middle-income country by 2020, focuses first on accelerating the pace of poverty reduction. The report suggests that the government should promote the pro-poor aspect of its national growth agenda – following a path similar to that of Brazil over the past decade. This requires policies designed to raise incomes through job creation and family planning. But the report also emphasizes the importance of improved education, better health care and broader access to such basic services as safe drinking water and adequate sanitation.

Such measures cannot succeed without intensifying applications of STI. Indeed such measures are crucial to achieving the Millennium Development Goals. In addition, the *Rwanda Vision 2020* report emphasizes the importance of building the necessary infrastructure for improved transportation and communication. Here again STI must play a pivotal role. Finally, the report stresses the significance of combating corruption and fostering an environment that rewards competence and accomplishment rather than tolerating connections and deception. The scientific community, which places a high value on transparency and excellence, can serve as a model for this effort. It will certainly be a beneficiary.

Rwanda's first *Poverty Reduction Strategy Paper (PRSP)*, which covered the period from 2002 to 2005 and was endorsed by the IMF, provided the analytical framework for transforming the lofty ideals presented in the *Rwanda Vision 2020* report into an action-oriented plan. *PRSP* emphasized the need to focus on initiatives to recover from the dire impacts of war and genocide in the mid 1990s. It called for increasing food supplies to meet the nutritional needs of the population and for rebuilding – and expanding – the country's transportation and institutional infrastructure, including education, health care and housing.

Progress has been achieved in some areas, most notably education. Health care and housing have also improved. Yet obstacles, particularly in administration and management, have continued to stand in the way of achieving even greater progress.

Rwanda's first *Economic Development and Poverty Reduction Strategy (EDPRS)*, which was approved in 2007 by the government, offers a medium-term strategy for poverty reduction and wealth creation for the years 2008-2012. Several broad initiatives underpin the strategy, including a programme for training personnel in such areas as finance, business, innovation and entrepreneurship.

The goal is to build on the growing strength of Rwanda's educational system and to provide additional skills that are needed to compete in the global market place. Such efforts require that learning be encouraged not just in school but also in the work place – and indeed throughout a person's life. *EDPRS* also seeks to address the country's institutional shortcomings by promoting such factors as greater accountability, rigorous project monitoring, a larger role for the private sector and closer alignment between the priorities of the nation and the priorities of donors.

With the support of the US Trade and Development Agency (USTDA) and the World Bank, Rwanda will seek to provide high-speed internet connections to every school. It plans to build a national fibre optic network linked, on one end, to the ocean-floor, high-speed cables that have been laid from South Africa to Sudan along the east coast of Africa and, on the other end, to satellite communications systems in each of Rwanda's 30 districts. The goal is to provide advanced internet access throughout Rwanda. In particular, the project is designed to serve schools, hospitals and health clinics, governmental offices and agencies, and community-based institutions with a broad and enduring network of ICTs.

Once completed, the government hopes to put the network to work on critical social and economic needs. For example, it plans to transform King Faisal Hospital in Kigali into a centre of excellence for medical research and care. Telemedicine will be an important part of the initiative as part of a larger effort to help ensure that the investments in ICTs reach the most remote and marginalized communities in the country.

To take advantage of its rapidly emerging capabilities, the government is also working in partnership with the One Laptop Per Child programme, based at the Massachusetts Institute of Technology's (MIT) Media Lab in the United States. A pilot programme, launched in 2007, led to the distribution of several hundred laptops among children in a semi-rural school in eastern Rwanda. The success of the programme – the children quickly and proudly learned to use the computers – led the government to begin a nationwide One Laptop Per Child programme in 2008. The goal is for 50% of Rwanda's primary school students to have access to a laptop by 2012.

Rwanda's troubled experience in the 1990s left country's economy devastated and much of the infrastructure destroyed. Most significantly, it decimated the population. Death and destruction often meant that all hope in the future was lost. With so few skilled workers (particularly in science, technology, business and management) and scant resources to rely on (Rwanda has neither the oil of Nigeria, the diamonds of the Congo nor the gold of South Africa), the country faced a desperate situation. Successfully building and rehabilitating Rwanda's infrastructure, restoring and creating public services and re-establishing a credible government in the eyes of both the people and the international community required the government to devise and implement multi-faceted reforms that would achieve near-term results for improving the well-being of people, yet that would, at the same time, remain focused on a long-term vision for sustainable development.

It is, of course, important to consider development by other countries, especially examples of "best practices" in the development and applications of STI that provide a blueprint for "leapfrogging" old technologies for new ones. Countries like Rwanda can learn a great deal from the STI-friendly policies adopted by developing countries that have made great strides in promoting science-based development.

There is, after all, no point in reinventing the wheel and there might well be value in retracing the tracks of other. Ultimately, however, strategies and developmental models initiated and implemented elsewhere must conform to each country's economic and resource conditions and must be attentive to history and culture. That is true not just in Rwanda but everywhere.

Rwanda's efforts to promote science-based development illustrate that a clear vision, committed leadership and a strategic plan of action that is ambitious yet doable are

essential for success. What is most encouraging is not just the progress that has been made, but that the rate of progress has been accelerating.

Rwanda does not presume to have all the answers. It does, however, believe that the level of progress that it has achieved makes it possible to serve as a model for other countries, just as other countries have served as models for Rwanda. This is especially true for countries in Africa.

What Rwanda has done, of course, it could not have done alone. It is grateful for the support it has received from national and international aid agencies and foundations. The United Kingdom (UK), for example, has provided aid to help build the country's educational system. The UK also funded an invaluable initiative that enabled the government to devise a national strategy for the development of STI. Sweden has invested substantial sums of money in the construction of Rwanda's ICT infrastructure. Germany has supported vocational educational initiatives, and the United States has financed public health programmes, especially for combating malaria and HIV/AIDS.

Rwanda has also benefitted from what some might consider unusual forms of cooperation, especially for a poor developing country. It is part of the East Africa Community (EAC), which encourages the free movement of labour across national boundaries. As word of Rwanda's success has spread across the region, Rwanda has welcomed an increasing number of professors and researchers from neighbouring countries, including Burundi, the Congo, Kenya, Tanzania and Uganda. It has also welcomed a small but increasing number of skilled and educated workers from the developed world – individuals who have been encouraged by Rwanda's success and who want to join the effort to build a better future for the country and all of Africa. For example, the rector of Kigali University of Science and Technology is from the UK. The head of the University of Kigali's School of Finance and Banking is from South Africa, and the director general of King Faisal Hospital is from the United States.

This kind of cooperation bodes well for Rwanda's future. It is cooperation based not on the heartfelt need to aid a poor and helpless country. Instead, it is based on the allure of a country building a bright future for its people that others – both at home and abroad – would like to be a part of. That, in a sense, is what globalization, at its best, is all about.

Rwanda's continued success in enacting effective policies for poverty alleviation, wealth creation and sustainable growth will ultimately depend on its ability to nurture an environment that values and supports STI. This means providing universal access to education and nurturing scientific centres of excellence, developing a strong and transparent legal and regulatory structure, building an adequate infrastructure and creating credible financial institutions and a transparent and accountable governmental decision-making process.

STI does not take root in a vacuum. Indeed only when the appropriate "nurturing" factors are in place can STI begin to flourish and make an indelible mark on society.

Rwanda's is in the "nurturing" stage. Ten years from now, if the existing trends continue on their course, we can expect that STI will be deeply rooted in society, offering continual nourishment to a strong and vibrant economy that extends a multitude of material benefits to its people.

If Rwanda succeeds, it would mean that in less than a generation it would have transformed itself from a country that was largely dependent upon subsistence

agriculture to one that embraces knowledge and innovation as fundamental tools for growth.

The Case for TWAS

The success of STI depends first and foremost on national policies. Countries set and pursue their own priorities, countries assemble their financial resources and determine how to spend them, and countries continually determine how to respond to the needs of their people. All of these critical factors largely determine the contours of STI policies. External factors can influence, but they cannot determine the intensity and breadth of a country's commitment to STI.

But in a broader sense the success of STI also depends on international exchange and collaboration, and that is where organizations such as TWAS, the academy of sciences for the developing world, come into play.

Over the past 25 years, TWAS has emerged as a leading institution in international science and respected voice for science in the South.

TWAS began with 42 members. Today it has nearly 1,000 members. Some 85% of the Academy's members are from the developing countries.

Many factors have propelled this welcome trend, including governments' increasing commitment to invest in science and technology, the rise of ICTs and better living and working conditions for scientists in the South – all of which have encouraged researchers to pursue their scientific careers in their home countries instead of migrating to the United States or Europe.

TWAS is proud of the contributions it has made to these advances. It has helped to promote science among both policy makers and the public and, equally important, it has helped to raise the profile of individual scientists in the developing world.

Election to TWAS confirms a scientists' contributions to his or her field. It also bestows prestige and recognition. Fewer than 25% of the scientists nominated for membership become members each year. As a result, TWAS can justifiably claim that its members represent the best of science in the South.

Through its research grants programme, since 1986 TWAS has helped hundreds of scientists at critical junctures in their careers. More recently, it has expanded this programme to fund research teams in 80 scientifically lagging countries.

By assisting both individuals and institutions, TWAS's research grants provide broad support for science and society in the developing world. By funding research groups in countries that are lagging in scientific proficiency, TWAS hopes to narrow the gap in scientific capacity between countries, not just between the North and South, but also within the South itself.

Another long-running initiative, the TWAS Prizes, celebrates the careers of top scientists, while the Trieste Science Prize, sponsored by illycaffè, recognizes the developing world's most eminent scientists. Together with the TWAS Prizes for Young Scientists, such activities highlight the important work that scientists carry out in developing countries and, perhaps more importantly, provide them with the recognition they need to progress in their fields.

TWAS has also been a strong voice for the scientific community in the developing world, helping to shape policy discussions with developing countries. TWAS has accomplished this through its support for scientific conferences and sponsorship of workshops on such critical issues as safe drinking water, the conservation and sustainable use of medicinal plants and renewable. The outcome of these discussions have been published in a series of volumes presenting examples of successful applications of science and technology to address fundamental challenges in the developing world. TWAS also works closely with a number of partners in both the North and South, including the African Union, the European Union, the Swedish International Development Agency, the US National Academy of Sciences, the African Academy of Sciences, the Organization for Women in Science in the Developing World (OWSDW), the InterAcademy Medical Panel (IAMP) and IAP, the global network of science academies.

Perhaps most importantly, TWAS serves as a bridge for South-South cooperation in science. TWAS's South-South Fellowships programme is one of the largest and most far-reaching initiatives for scientific capacity in the developing world. Each year, some 300 fellowships are made available for scientists from the poorest developing countries to receive training at universities and research centres in Brazil, China, India, Malaysia, Mexico, Pakistan and Thailand. The goal is educate the next generation of scientists and to develop a critical mass of capable scientists in all developing countries.

All of these actions are designed to help build a strong scientific foundation that can serve as a platform for effective policies to curb poverty, grow the economy and set the stage for sustainable development and innovation.

Over the years, TWAS has organized general assemblies that have become signature events in assessing the state of science in the developing world. And, it has forged strong ties with many other international scientific organizations that share TWAS's aspirations and goals. Increasingly, it has focused its attention and resources on addressing the needs of young scientists, and it is now taking steps to extend more responsibilities to its regional offices as part of a larger effort to decentralize its activities and bring its programmes and activities closer to the scientists and scientific institutions that it is trying to help. In addition, over the past several years, it has partnered with other organizations beyond the circle of collaborators it has worked with in the past – notably, the European Union, Microsoft Research and Elsevier.

STI in the Global Age

We have entered a new era of global science, marked by growing scientific capacity in the developing world and a significant closing of the North-South divide in science. TWAS is well positioned to serve as a bridge between the South and North in a broad range of scientific fields. As TWAS's new executive director, I plan to take advantage of the growing opportunities for global collaboration that will help broaden the reach and impact of the Academy.

I also plan to expand TWAS's presence in areas related to science policy, again with partners in both the South and the North. My hope is to extend the Academy's reputation for excellence by raising TWAS's profile in fields such as science diplomacy and science education.

STI is no longer the province of just the North. And, I might add, the experience of my own country of Rwanda over the past decade shows that STI is now a primary force for

positive change in poor countries too. This irreversible trend, both in attitudes and applications of science to development, presents profound challenges and opportunities for TWAS as it seeks to build upon its hard-earned reputation as the "voice of science in the South."

TWAS's track record suggests that it can successfully navigate the new world of science that is emerging across the globe – not just to benefit its members but, more importantly, to advance science-based development in all countries.

We have a rare opportunity to make historic changes in the role that STI plays both in developed and developing countries and in addressing critical challenges related to the global economy and the environment. It is an opportunity that should not be missed. ■