AN ANALYSIS OF SCIENCE, TECHNOLOGY AND INNOVATION FOR REGIONAL DEVELOPMENT

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SUMMARY

The use of S&T to achieve accelerated socio-economic development in many developing countries has largely been unconvincing. Essentially, science has often been applied to attain short-term goals when most of its benefits are seen in the long term. Furthermore, injudicious grouping of innovation with the tools of science and technology has further confused their definitions and functions. This paper therefore explores the relationship of these factors in Caribbean policy development and execution. Emerging from this is the notion that science is sufficiently different from both technology and innovation for each to merit distinctive handling. It is being advanced that technology policies should lead in policy formulations, while science policies should provide the logical underpinnings and knowledge to permit relevant technological selection, adaptation and use. In this model, government is seen as the main S&T infrastructure pivot encouraging linkages along value chains to create dynamic systems of innovation. Understanding the creative benefits of the scientific research method in governance and business is seen as vital.

UN ANÁLISIS DE LA CIENCIA, TECNOLOGÍA E INNOVACIÓN PARA EL DESARROLLO REGIONAL

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RESUMEN

El uso de la C y T para alcanzar un desarrollo socio-económico acelerado en muchos países en desarrollo no ha resultado muy convincente. En esencia, la ciencia a sido aplicada a menudo a fin de obtener resultados a corto plazo cuando la mayor parte de sus beneficios se obtienen a largo plazo. Además, la asociación poco juiciosa de la innovación con herramientas de la ciencia y la tecnología ha confundido aún más sus definiciones y funciones. Este ensayo explora la relación entre esos factores en el desarrollo y ejecución de políticas en el Caribe. DFe ello emerge la noción que la ciencia es suficientemente diferente de tanto tecnología como innovación para merecer cada una de ellas un manejo distinto. Se adelanta que las políticas tecnológicas deben predominar en formulaciones de políticas, mientras que las políticas científicas deben proveer los soportes lógicos y el conocimiento para permitir una selección, adaptación y uso apropiados de tecnologías. En este modelo, el gobierno es visto como la palanca principal de la infraestructura de C y T, auspiciando vínculos a lo largo de cadenas de valor para crear sistemas dinámicos de innovación. Comprender los beneficios creativos del método de la investigación científica en la gobernabilidad y los negocios es apreciado como algo vital.

Context

In the Caribbean, science and technology (S&T) have had inconsistent support and consequently disappointing results. Research and development (R&D) and other S&T institutions have been created and policy and plans written, but coherent knowledge infrastructures have yet to emerge. University departments and research centres devoted to S&T have existed for decades, but the transformative development effects of these tools, as seen in the industrialized and recently developed countries, are still only forlorned hopes in the region. Confidence in S&T as growth instruments still remains elusive.

On top of this, countries in the Caribbean face serious socio-economic problems that only scientific research, innovation and knowledge can solve. For example, those of clean and affordable energy, food security and growing degradation of fragile environments persist as chronic challenges. These difficulties have contributed to anaemic economic growth with insufficient number of jobs and possibilities for high level occupations, with heightened social and political tension, much acrimony, class discrimination and blatant inequality.

Although S&T have been publically lauded they are still considered optional extras. It is not strange for them to be given ceremonial support in one political administration, to be totally ignored by another. At best, S&T receive minimal affirmation from fad and fashion and less so for the purposes of serious national development.

The region has produced high quality graduates in science and engineering; however, the majority of them have to ply their talents abroad. At the same time, significant sums are being spent on foreign consultants, technological advice and equipment, some of which are entirely inappropriate to local circumstances and conditions.

KEY WORDS / Innovation / Public Polices / Science / Socio-Economic Development / Technology /

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UMA ANÁLISE DA CIÊNCIA, TECNOLOGIA E INOVAÇÃO PARA O DESENVOLVIMENTO REGIONAL.

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RESUMO

O uso da C e T para alcançar um desenvolvimento socioeconômico acelerado em muitos países em desenvolvimento não tem resultado muito convincente. Em essência, a ciência tem sido aplicada com frequência com o fim de obter resultados em curto prazo quando a maior parte de seus benefícios se obtém em longo prazo. Além disso, a associação pouco judiciosa da inovação com ferramentas da ciência e a tecnologia tem confundido ainda mais suas definições e funções. Este ensaio explora a relação entre esses fatores no desenvolvimento e execução de políticas no Caribe. DFe isto emerge a noção que a ciência é suficientemente diferente de tanto tecnologia como inovação para merecer cada uma delas um manejo distinto. Adianta-se que as políticas tecnológicas devem predominar em formulações de políticas, enquanto que as políticas científicas devem prover os suportes lógicos e o conhecimento para permitir uma seleção, adaptação e uso apropriados de tecnologias. Neste modelo, o governo é visto como alavanca principal da infraestrutura de C e T, auspiciando vínculos ao longo de cadeias de valor para criar sistemas dinâmicos de inovação. Compreender os benefícios criativos do método da investigação científica na governabilidade e os negócios é apreciado como algo vital.

Logical Underpinnings

Differences between science, technology and innovation

To start this examination, it is worthwhile to note that there is a tendency to associate science with technology so closely that they are dubbed a linear continuum, while innovation is now the new craze which is mentioned in every matter concerning S&T. It is illogically nailed into the duo of S&T to make a more confusing trio: science, technology and innovation.

There is no doubt that there are organic associations between science and technology and these have profound influences on innovative capacity; however, there are natural discontinuities in these relationships that should be respected, especially when execution and implementation are concerned (Ventura, 2013).

There are clear distinctions between science and technology, and even more variance between these and innovation. While S&T are developmental tools, innovation speaks to imaginative outlooks, or novel ways in which these tools may be used.

General science policy considerations

a) *Science policy is a component of public policy.* It is instructive also to recall that science policy is a component of public policy and not an independent stand-alone entity (Neal *et al*., 2008).

Science policy may be thought of as the "processes and players involved in making governmental decisions, the factors that influence their decisions and the manner in which those decisions are carried out" (Neal *et al*., 2008). It seeks to arrive at the best course of scientific actions for addressing issues of public concern. While policy for science is public policy governing matters of science. It refers to the rules, regulations, methods, practices and guidelines under which science and scientific research are conducted.

So science as public policy must be in harmony with what is expressly required for the advancement of that policy. Without leadership that is sufficiently seized of the usefulness of science to development imperatives, such exercises are efforts in futility. This is more so in attempts at sustainable development without these being fully embraced or clearly defined. Science for policy making is dependent on national conditions and ambitions. Here the scientific research method is the key to uncovering and understanding the value of evidential information and verifiable knowledge in socio-economic policy development and execution. There are however other features, such as wide support of excellence and creativity that are crucial and merit attention.

Policy that is informed by science is used specifically to frame and uphold laws, regulations and standards, pertaining to a range of public issues to allow them to be properly handled. Among some of these are questions and problems pertinent to, *inter alia*, water quality and management, pesticide usage, food processing and handling, and logical decisions concerning climate change, and emerging scientific issues, such as in biotechnology and nanotechnology safety, as well as social challenges, such as crime and violence.

b) *Policy for science*. Science for improving socio-economic policy making and execution is different from policy for science but is related to it, and can be seen as the application of policy to regulate and oversee the conduct of science. Policies for science are characterized as decisions about how to find, or structure the systematic pursuit of knowledge. This aspect of science is often well expressed in policy framework documents. These are carefully articulated in most jurisdictions to establish criteria for generating, identifying and choosing alternatives, to improve investments for R&D, increase the caliber and numbers of scientists by improved science teaching and learning, and expounding ways to communicate and apply scientific results.

Providing for science is still a work in progress and a science of scientific development and use seems to be in order, as there is much room for individual creativity, ingenuity and judgment in this field (de Sola Price, 1964).

Science is so important to the sustainability of a civilized life on this planet that each country should be encouraged to contribute to this global effort, and better endowed nations should help less equipped ones to do so (Ventura 2012a). States should be accorded some international recognition for their contributions to the global scientific effort, perhaps a Nobel-like prize for extraordinary efforts (Ventura, 2001).

It is important to emphasize that science policies are preludes to actions and for policies to be translated into action, planning must follow policy and to give planning purposeful practicality, actions plans have to be devised.

c) Science different from technology. As mentioned before, science and technology possess fundamental differences. Science uses the scientific research method to unravel well defined questions by the collection, analysis and interpretation of data, while technology (Arthur, 2009) is built on other more practical recursive principles (Table I).

The differences between science and technology are enough to advance the idea of separate but related policies and plans. Such policy distinctions were highlighted by Sa-

TABLE I
FUNDAMENTAL PRINCIPLES OF TECHNOLOGY

A technology is a combination of components for some purpose, organized around a central concept or principle.
Primarily a technology consists of a main assembly that carries out its main function, plus a set of supporting assemblies to provide a working architecture.
Technologies are created from combinations of what already exists, each being a miniature technology.
All technologies harness and exploit some natural effect or phenomenon, or usually several.
Technology builds from the continual harnessing of natural phenomena uncovered by science.

gasti (1979) and are displayed on Table II. Essentially, the conceptual mindset, the expectations and the time lines, are different. Pure basic scientists are mainly interested in research outcomes, or discoveries, to illuminate their field of endeavour, and they are willing to devote an extended period of time for returns. While those who see their work as responses to practical and production imperatives are impatient of outcomes.

Moreover, science appears to go in different directions from technology (Nightingale, 2000). This is depicted on Figure 1. So much so, that there are anomalies in the logic of S&T progression; for example, technology often comes before the science that explains it, excellent science does not always lead to excellent technology, and technology is localized while science is freely available.

Technology policies therefore have a different set of priorities from science policies as seen on Table III.

In trying to understand these observations, it should be recalled that science does not linearly lead to technology and innovations, as shown on Table IV. Therefore, to promote innovations certain aspects of training are instructive, as suggested in Table V.

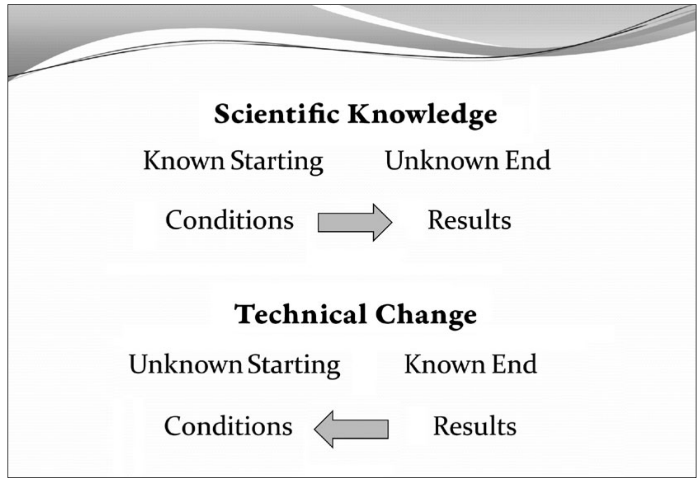

Figure 1. Science & Technology: different directions.

TABLE II
DIFFERENCES BETWEEN SCIENCE AND TECHNOLOGY POLICIES

	Science Policy	Technology Policy
Objectives	To generate scientific (basic and potentially useful) knowledge which may eventually feed into social and economic uses, and which will allow understanding and keeping up with the evolution of science; to develop a base of scientific activities and of human resources linked to the growth of knowledge at the world level.	To acquire the technology and the technical capabilities for the production of goods and the provision of services; to develop the national capacity for autonomous decision making in matters of technology.
Main types of activities covered	Basic and applied research, which generate basic knowledge and potentially useful knowledge.	Develop, adaptation, reverse engineering, technology transfer and engineering which generate ready-to-use knowledge.
Appropriation of the results of activities covered	Results (in the form of basic and potentially useful knowledge) appropriated by disseminating them widely; ownership ensured by publishing.	Results (in the form of ready-to-use knowledge) remaining largely in the hands of those who generated them; appropriation of results ensured by patents, secret know-how, and human-embodies knowledge.
Reference criteria for the performance of activities	Primarily internal to the scientific community; evaluation of activities based mainly on scientific merit, and in a few cases on possible applications.	Primarily external to the technical and engineering community; evaluation of activities based mainly on their contribution to social and economic objectives.
Scope of activities	Universal; world-wide validity of activities and results.	Localized (firm, branch, sector or national level); activities and results valid in a specific context.
Amenability to planning	Programming possible for only broad areas and directives; results dependent on the capacity of researchers (teams and individuals) to generate new ideas; large uncertainties.	Stricter programming of activities and sequences possible; little new knowledge generally required; systematic use of existing knowledge involved; less uncertainty.
Dominant time horizon	Long-and medium-term.	Short-and medium-term.

TABLE III
PRINCIPLES OF TECHNOLOGY POLICIES

It can be defined as systematically stimulating technical progress - enhancing skills, knowledge and procedures applied in the production of goods and services.
It accommodates: - adjustments to technological change - framing and accelerating technological change
It aims at enhancing a firm's, industry's or economy's competitiveness and fostering economic growth.

Innovation Possibilities

As with S&T, innovation also calls on a different mindset, requirements and emphases (Government of Canada, 2009). Innovation flourishes where there are national linkages giving rise to what can be referred to as systems of innova-

TABLE IV
THE ROLE OF SCIENCE IN INNOVATION

To understand and predict patterns
Screens out unlikely alternatives
To fathom how things function
Does not provide answer to technical problems
Provides understanding about how technology works
Reduces effort and cost in solving complex technical problems
Improve research techniques, example: instrumentation
Access to global scientific networks

TABLE V
HOW SCIENTIFIC TRAINING AIDS INNOVATION

Provides improved research skills and technological savvy, use of instruments, insights to novel possibilities, and convergence of advancements and techniques to materialize ideas.
Opens access to global scientific networks to solve problems beyond immediate understanding and support services
Better appreciation of collaborative and competitive behaviour
Establishes know how and who is who in specific fields
Builds self- assurance and confidence

tion, but first, a distinction should be made between invention and innovation.

An invention is an identifiable and discrete contribution to technical knowledge, sufficient to warrant the consideration of feasibility studies, the drawing up of plans, and the construction of working models or pilot plants. Innovations are subsequent successful inventions that appear in commercial or practical use, as new arrangements, value added products, processes or services. Generally, innovations are said to occur when ideas move into enterprises, or improved products or processes. For this to occur regularly, many different institutions and actions are required to work in unison.

In many developing countries with relatively well developed S & T communities, there are a number of inventions, but very few innovations, and consequently lower than expected diversification and productivity rates. In these situations, infrastructures for R&D are present but investment systems for translation, transfer and execution, are paltry or absent. Government must correct this deficiency as the private sector will not.

This means that the usual set of scientific, technological, engineering and marketing capabilities are not enough to meet current development and environmental demands (Ventura, 2000). Instead, a wider set of competencies must be installed to fashion dynamic systems of innovation. They include openness, experimentation, coping with uncertainty, dealing with change, questioning proclaimed truths or fads, building trust, working within partnerships across ministries, as well as, between firms, universities and research bodies, and active learning and adaptive policy making and monitoring.

These competencies are not easily acquired during conventional training that relies heavily on codified knowledge. They instead depend more on tacit knowledge and experiences acquired during implementation. Additionally, such capabilities cannot be easily acquired from the outside, or imitated by rote. They are acquired by actions, feedbacks and internalization as individuals or organizations learn, and become more informed and insightful as they execute.

Entire systems to promote and support innovation consequently arise spontaneously as attitudes and structures converge in efforts to effectuate and produce. Features of innovation systems are characterized as networks of economic agents, together with institutions and policies that influence their innovative behaviour and performance.

Innovation therefore can be visualized as an iterative process in which enterprises interact with each other, as they are supported by institutions and a wide range of organizations, to bring new products, new processes and new forms of organization into economic or social use.

To do this a distinction between information producing organizations, such as universities, research bodies, policy councils, commissions and firms, as separate from institutions which convey a set of habits, routines, established rules and practices, or attitudes and laws that regulate the relationships and interactions between individuals and groups (Mytelka, 2000). These institutions are crucial because they can condition behaviour and define roles, as they can constrain activities and shape expectations. Importantly, innovation systems help to induce confidence in novel production, as risk assessment is made clearer and easier to conduct, and risk insurance policies can therefore be more readily installed. This is especially comforting to bankers (Ventura, 2012b).

Policy Requirements for Innovation

Key elements

For innovation, multi-directional links and networks must be established along value chains to ensure unrestricted information and knowledge flows and willingness to act and take risks. This will not happen without thoughtful state support and S&T polices with clear strategic objectives and priorities, together with a high level of coherence and acceptance in the system.

Accordingly, six key elements underpin innovation. They are imagination, executions, linkages, investments, learning, risk assessment and support of excellence. Policies should take these into consideration because they are pivotal in that they set the parameters within which the different actors make decisions about technological investments, learning, sharing and the innovative spirit itself.

For innovations to occur with regularity, space must be made for creativity. Unfortunately, conventional management approaches to the use of knowledge are not conducive to innovation. (Dugen and Gabriel, 2013). Creative decisions cannot be made by consensus generated by conventional committees, where consistency are uniformly the acme of desirability. Breakthroughs require novel thinking and actions, not uniformity or sterile conformity.

The quality of partnerships

Despite similar investments in infrastructure, skills and education, there are wide success divergences between countries, communities, towns, industries and research centres. The complexity of how S&T influence development makes it difficult to explain these differences. However, recently it has been observed that where social networks are stronger, more dense and dynamic, returns on investments are more rewarding. One may say the quality of innovation systems matter more than previously recognized.

New Approaches to Science, Technology and Innovation Policies

Trust in science and its technologies

From the foregoing, a number of approaches for improvement in S&T in the Caribbean can be identified (Table VI).

Science and technology policies have not been effective in many jurisdictions despite much effort by science professionals. Perhaps too much emphasis has been placed on policies to promote science and not enough on how they will impact development. Maybe in the beginning more emphasis should be placed on the importance of science to public concerns and sustainable goals, than on science itself.

TABLE VI
WAYS TO IMPROVE CARIBBEAN S&T

Build trust in science and its technologies
Exploit short-term effects of technology
Sustain efforts to operationalize polices and learn
Engage voters and other private sector stakeholders in the enterprise
Strengthen the quality of partnership among S&T units
Encourage linkages to deepen and extend innovation systems
Reconfirm the use of the scientific research method in R&D institutions and decisions

However, even when there appears to be sufficient S&T competence and articulated development goals, there was often not enough confidence within political and private leadership to assertively accept and implement crucial elements of relevant science policies.

Strategies to remedy this situation will rely on building trust in the ability of science to deliver, by improving relevant insights and understanding by those who are to directly benefit from such policy directives. Demonstrations of scientific and technological knowledge utility in attending to urgent issues are good ways to solicit support. This is where technology policies can palpably demonstrate short term efficacy (Ventura, 2013).

Key role of governments and politicians

Two facts must be recognized with respect to governments' role in S&T. First, the direction and rate of innovation are what actually drive the growth of economies (Mazzucato, 2013) and secondly, governments are the main risk takers in education, technological development and dissemination and use of information. The private sector is often too risk averse to take on these elementals. So to join the knowledge industry and to pursue innovative S&T, the role of government is central. Grudgingly Caribbean governments have taken on these obligations with marginal success. To become more influential, they must become insightful, creative and entrepreneurial. In other words, the state must become the leader and apex of national innovation systems.

Essentially, major investments in the building of S&T infrastructures are largely the prerogatives of governments in all countries, developed, recently developed and developing states. (Mazzucato, 2013) Science and technology cannot be left solely to the private sector and market initiatives, because of their uncertain nature, and the demand for expenditures in education for which there may be no guarantee of immediate or easily identified material returns.

Another vital role for government in domestic S&T advancement is to use procurements procedures, commissions and regulations, to boost the production of more competitive local products and services, by utilizing more domestic S&T and engineering skills. However, parliamentarians have problems distinguishing reliable from unreliable scientific evidence. This is mainly due to a general lack of understanding of the scientific research method by decision makers. So politicians can benefit from training in the significance and limitations of this method (Ventura, 2000).

Scientists and politicians work form different epistemological frameworks which must be reconciled. It will be difficult however to get senior politicians to go back to school, but it may not be as difficult to entice young politicians to become educated about the scientific process and the global knowledge economy, thus making the next generation of political leaders more scientifically literate and technologically savvy.

Clearly, science advisers in government can help to remedy this situation, especially if they take an open inter-disciplinary, multi-disciplinary, cross boundary and trans-disciplinary approach to government challenges to help bridge the conceptual gaps between politicians and scientists.

Engagement of voters

In democracies it is instructive to have voters in the corner of science. This will only materialize when demonstration and appreciation of its value to ordinary life and livelihoods become common place. Science and technology professionals must become more adept at reaching out to laymen and seriously consider their views and experiences, in other words bringing them more into policy/planning processes. Accordingly, science, technology, innovation and economics should be primarily about peoples' health, dignity, contentment and happiness, and not only about the accumulation of material and banal accoutrements. Media houses are the *de facto* educators of the public and therefore are central to these efforts; consequently, scientists must come to understand the media and its operations, and media personnel the varied aspects of science reporting.

Scientific temper of business and civic leaders

The problems of scientific literacy do not stop at political leaders, but extend to civic and business captains. Here many harbour a glimmer of appreciation that scientific knowledge can make meaningful contributions to all types of businesses and can offer resolutions to social issues, but they are not yet sanguine enough to make adequate investments in local R&D.

Others clamour for innovations and entrepreneurship, but do not recognize that these are curtailed by lack of scientific information and technological insights (Ventura, 2012b). Ways will have to be developed to keep leaders informed of world-wide scientific developments that are of local currency. Leaders must therefore be willing to employ workers trained in science to make links with relevant scientific circles and activities.

Sustained Investments in S&T for Socio-Economic Development

Operationalization of policies

In the Caribbean there are few long term attempts at building adequate technological and engineering standards, infrastructures and skills. For some, technology simply means more computers and connections to the internet. So investments to meet social and competitive needs require visionary and predictable financing to enable professionals to aspire not just to research publications, but also to actually create products from research results. Consequently, policies must be accompanied with specific ways to operationalize them. To do this, policies must address the need to establish close links with the productive sector to increase economic productivity and build trust. However, it is unrealistic to expect researchers to be discoverers, inventors and innovators, as well as entrepreneurs and engineers, at the same time. There have to be skills and infrastructural specializations for efficacy, to allow for timely diffusion, implementation and production.

Innovative funding mechanisms have to be established to entice the private sector to invest more in S&T activities. These types of considerations mean more engagement with the Ministry of Finance than merely with the Ministries of Science or Education, and of course, direct contacts with private sector organizations, such as banks and manufacturing associations.

Plans to improve innovation

Innovation will not flourish just because there are bright young zealous capitalists. Without scientific and technological insights and knowledge, the range of innovations and business start-ups will continue to be limited.

Establishing and using innovations systems that are strongly linked into the global knowledge networks are indispensible for small economies. To make this link functional and active, there is need for creative and scientifically assured research communities and receptive productive sectors.

Adherence to scientific research principles

The foundation of scientific success is the scientific research method, which can be deployed to accomplish different tasks, as described in the Stokes model. There are four quadrant in this model (Narayana *et al*., 2013) the pure basic research quadrant (Niels Bohr) to extend fundamental understanding; the second quadrant is the Pasteur quadrant, where inspired basic research is used to solve practical problems; then there is the pure applied quadrant (Thomas Edison), here inventors strive to solve practical problems. The fourth quadrant is often not stressed in the model, because in actuality, there is no basic research being conducted and applied work is also very weak.

Many Caribbean research bodies seemed to be stuck in these last two quadrants with very little research being conducted. Essentially, the emphasis is on short-term outcomes heuristically determined. So much so, that the effectiveness of the scientific method is forgotten and success is measured in technological imitation and repetitive products. It therefore seems worthwhile for the various aspects of the research method to be reintroduced and be reconfirmed in many research institutions as the tool that holds the most promise.

Assessment of scientific impact

There is no doubt that investments in science can create jobs. Nevertheless, investments in science do not guarantee short-term economic growth nor extensive job creation. But this is not true of long term economic benefits, as confirmed in the fact that more than three-quarters of post-1995 increases in productivity growth can be traced to science investments (Lowe, 2009). Furthermore, recently economic progress has been more closely associated with basic scientific activity than simple technological transfers (Jaffe *et al*., 2013). Apparently countries that indulge heavily in basic scientific work encourage more logical thought and reasoning throughout their societies, occasioning better decisions. Moreover, a science education is the best preparation for jobs which do not yet exist but will inexorable emerge with technological advancement.

Giving technological policy the lead in S&T plans appear to be counter to this observation, but please remember that S&T policies and plans are now largely being ignored by both leadership and the population at large in scientifically weak states. Technological development and transfer are being given priority here to highlight the short-term utility of S&T. However, science is not being ignored, as it is being given more focus through the instrumentality of technological identification, selection, modification and application.

Conclusion

Because technologies have short-term and specific leverages on businesses, industries and communities, technology policy is being advocated as the lead factor in science and technology policy/planning articulations. With this arrangement, it is anticipated that users will play a more attentive and determining role. Additionally, users will be inclined to become savvy with technological trends and transfers to make adequate selections. This will require more understanding of scientific developments and their anticipated impacts on technologies and their derived products and services and potential markets.

Of political significance is the fact that electors, in their own self interest, will exercise greater say in science and technology policies, plans and implementation, because of the immediate solutions technologies can bring to a variety of problems, as opposed to more delayed and unpredictable social contributions of science.

In this scenario, crafting and executing science and technology policies, plans and strategies will be instigated more by private sector leaders, managers, producers, consumers and customers, rather than exclusively by politicians, scientists and technologists.

These operatives must become partners in innovation systems led by governments. Here creativity, excellence and risks are to be encouraged by the ways in which investments are made.

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