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How to make the most of science and technology investments in developing countries

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Science is the new cool in economic development. National investments in science and technology are joining their venerable counterparts in health, education, finance and workforce in terms of national strategic importance. The approach makes sense. Good science and technology investments can help developing countries to push their development faster and smarter. As Niosi (2010) points out, while horizontal policies may strengthen existing sectors, innovation and investment in research and development (R&D) are necessary for new sectors to emerge. For example, smart, focused investment in biotechnology has been an important key to Singapore's growth. In a traditionally agricultural economy like Vietnam, the right policies and the right people were critical in building a health biotechnology industry (Ca 2007). In the future, local science will be necessary to ensure that drugs developed for wealthy older Europeans are not simply sent to Africa, but restructured for the needs of poor African women and children. Local knowhow is necessary to adapt cellphone technologies to support teachers in the classroom or to help fishermen get information about the best prices for their catch.

Local science and technology, driven by local needs can also stimulate the type of Pasteur's quadrant research that can transform economies – basic research that is use-inspired, just as Pasteur's discoveries were driven by the late C.K. Prahalad (2009). Such local innovations may also create internationally competitive firms. Research by Breznitz and Murphree (2011) demonstrates that in China, mom-and-pop shops, small businesses that are typically owned and run by members of a family, are offering prototyping with unprecedented quality, flexibility, and speed-to-market. The resulting unique products, like the Unterruptible Power Supply batteries developed in Duongguan, are highly demanded by start-ups and R&D divisions in the U.S.. In India, telecommunication companies focused on constrained urban Indian markets are finding the resulting low-power modules being demanded throughout the world. Eric Fuchs (2009) has similarly found in East Asia that manufacturing technologies and the efficient plant size are determined by the size of regional markets; so that for "nations to achieve advantages in particular technologies, they must follow their own path". And a recent World Bank Report (2013) documents how in Africa, the government facilitated push to support innovative new technologies, has led to Africa leading the world in ICT banking technologies like Safaricom that not only have found relevance in rural areas in Africa, but also in the U.S..

Alas, despite the promise, we know far more about making wise investments in health, education, finance and workforce than we do in science. How *should* science best be fostered? The answers to that are not well known but are emerging, in as the former US President's Science Advisor John H. Marburger III put it "a science of science policy". What we have learned from this new field can be used by developing countries as they implement a scientific approach to making their science investments. They may even have an edge, since they have not overinvested in archaic approaches.

Building a "science of science policy" in developing countries

Ironically, probably the biggest reason for the lack of a scientific basis for science policy in the developed world is that science investments are largely run by domain scientists with no expertise in either science policy or evaluation, rather than trained experts. Such an approach is akin to putting untrained individuals in charge of building bridges, mapping the human genome or searching for the Higgs Boson. If there is to be an improvement in the information available for the management of the national science and technology enterprise, the practice of science policy must be professionalized. As Marburger noted, "policies can be formed and carried through rationally only when a sufficient number of men and women follow them in a deep, thoughtful, and open way. Science policy, in its broadest sense, has become so important that it deserves the enduring scrutiny from a profession of its own". The challenge for developing countries is to think carefully about how to structure their nascent science and technology enterprises to incorporate evaluation and evidence from the beginning.

A number of developed countries have begun to build communities of practitioners and researchers who are focused on creating a more scientific basis for science policy. The United States established both a White House Interagency Group of the major science agencies and the National Science Foundation established a research program called the Science of Science and Innovation Policy (SciSIP). Japan and Norway have begun similar programs. The results have led to a US and joint EU-US science roadmap and have given important insights on the effects of policy changes. E.g. it was shown that a tightening of the visa policy for Chinese researchers decreased the probability of postdoctoral participation among temporary visa holders by 24%. Furthermore the effects of changes in public funding for stem cells have been analysed. Although it initially clearly reduced the amount of U.S. based research that was done in a particular field, U.S. based scientists reacted by changing the nature and expanding the level of their international scientific interactions (Lane & Black, 2012). Information provided by communities of practitioners and researchers could prove valuable for policy makers worldwide.

Developing countries need to do no less. Each country could start by establishing a committee of leaders responsible for guiding science investments. The next step is to build a common conceptual and empirical framework so that any analysis can be generalized and replicated – the essence of science that will allow both sides of the global society to collaborate openly and frankly in how to use science and technology to address a number of Millennium Development challenges including education, hunger, and disease and addressing important issues like climate change.

In this endeavor, the development community is an important intermediary translating and adapting the practices that have proven their effectiveness outside the developing world. Many of these solutions are already advocated by international organizations like the United Nations and the World Bank. Among others, the latter is supporting establishment of technological hubs and platforms to improve interactive learning and innovation capabilities in many developing countries; for example building to improve the links with scientific diaspora in Croatia to boost international S&T collaborations and take the country to the new level of scientific development. Projects like this are replicable and useful across a range of emerging economies. Non-governmental organizations, national development agencies and think-tanks are another point of help and advice to promote similar projects and boost the countries' innovation performance.

Building a framework to support science and innovation

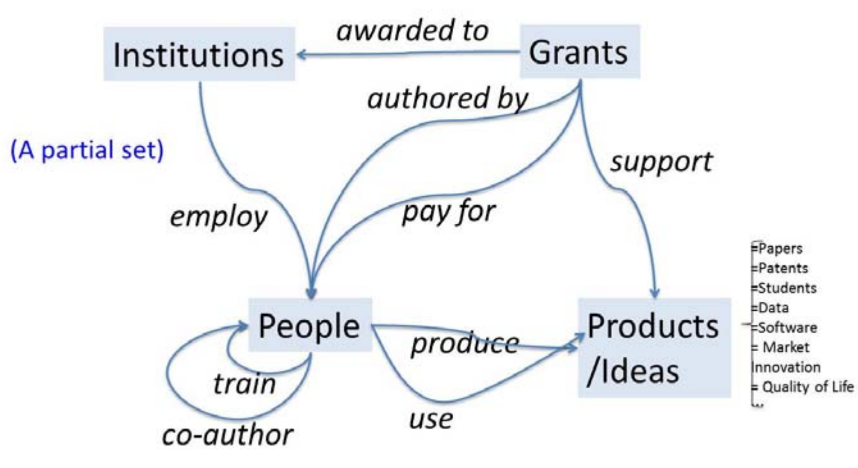
Getting the right conceptual and empirical framework matters, lest resources and people get squandered because incentives are wrong. The emerging approach is to recognize that science is fundamentally about the creation, transmission and adoption of ideas not about counting documents. The conceptual and empirical focus is then on identifying and supporting scientists and scientific networks – the trailblazers, pioneers, settlers, sodbusters, ranchers, and developers of science (Warsh, 2012). This is in stark contrast to previous approaches, which treat science as a black box (or a slot machine) where, when large amounts of money are spent – a magical 3 or 4 percent of GDP -- then "a miracle occurs" in terms of innovation. The more scientific approach structures measurement to describe *who* is being funded to collaborate *with whom* and *where* to do *what* (Figure 1). This correctly identifies the change agents as researchers and research networks and renders current approaches, derived from the reporting requirements of previous decades, which arbitrarily ties publications and patents to a single particular funding sources (the right hand side of Figure 1) both misleading and irrelevant.

Working from this framework has important science policy implications. It means that science agencies should focus on people not documents. Funders should identify good researchers as they are developing, fund them to help build and expand their research networks, reward them for training good graduate and undergraduate students, and build the infrastructure necessary to do their science, rather than building massive infrastructures to count publications and patents. This is all feasible in an era of big data and cyber–infrastructure: existing data can be repurposed and 21st century technologies applied.

In other words, at the core of every science centered innovation is the people who have ideas. So modern science and innovation policy should not simply rely on counting patents and publications – which are rare in developing countries anyway – but on identifying promising and productive individuals and their scientific collaborations which are critical to fostering good science and technology transfer. Policy should also recognize that students play an important and unrecognized role. They can be the key to the transfer of technology from universities to the private sector. Developing countries, which are just starting to build research funding systems, can incorporate automated systems which can tell them which students are working on which funded projects, and support and retain them in the country (or encourage them to repatriate if they leave) with relatively low burden and cost.

It's an old saying that you can't manage what you can't measure – so developing countries should build systems using modern approaches to describe what research investments are being made, and how they are complementary to investments made in other countries: so that research institutions can identify their research strengths, gaps, and the changes over time. It is unnecessary to rely on arbitrarily created taxonomies of science that expect researchers to fill out forms to categorize their activities. Google and other companies do not require anyone to fill out forms to tag billions of documents; they use natural language processing techniques to mine massive amounts of text. Using naturally generated topics permits science agencies to identify emerging fields, interdisciplinary collaborations and compare their investments against their international counterparts. The approach can be as simple as setting up grant

Figure 1: Science Funding and Results



Source: Foster & Lane, 2013

proposal systems that capture proposal data in a structured format (rather than the unstructured format used by developed countries) and automated CV systems (like the Brazilian Lattes system) to automatically capture researcher interactions and their areas of research.

Of course, it is critical that the information can be used – so it must be brought together in an easy to use and intuitive framework. Since the community consists of both researchers and policymakers, the goal here is to both create knowledge and to make it useable for policymakers. Some examples of how that research is yielding practical results can be seen from the White House's prototype R&D Dashboard and the wireframes developed for the French Institut National de Cancer's HELIOS project.

The results in practice

An important precondition to evaluate the impact of science investment is an improvement in the method of measurement. There, helpful tools like STAR METRICS built in the United States, can be used by both researchers and university administrators to make better decisions and to rigorously describe the results of science investments. So, the answer to the question of how should science be fostered is: use a scientific approach. Build a scientific community and create an intellectually coherent, generalizable and replicable body of measurement and analysis. Thoughtfully address privacy and confidentiality issues, which are quite complex in the new era of big data (Bender, Lane, Nissenbaum, & Stodden, 2014).

Developing countries have a clear edge because as they are beginning to build their scientific portfolios, they can use new, rather than archaic technologies. Scholars studying catch-up growth clearly support this approach. Based on massive historical evidence, they say that developing economies have particular advantages compared to the leaders as, first, they already know the market needs and can invest in the sectors where biggest returns are expected, and second, they do not have the burden of older industries and research centers to care about (see, for example, Gerschenkron's famous *Economic Backwardness in Historical Perspective* 1962). Yet, all those subscribing to this new development agenda also have to improve their social capabilities and have enough finance to support any large-scale effort – a limitation where the development community should be eager to help through existing and new means of aid and assistance.

There is reason to be optimistic about the potential for science and technology policy to spur development. Success stories of South Korea, Taiwan, Singapore, Vietnam, and others provide distinct backing of this vision. Not only have they grown economically, their human development index have improved significantly over the last twenty years. For example, South Korea's high-technology exports sky-rocketed from $10.8 billion in 1990 to $122 billion in 2011 with the gross R&D expenditure rising from 2.61 per cent in 1996 to 3.74 per cent of GDP in 2010, while the country is ranked 12 in the UN Human Development Report 2013. More impressive, South Korea has improved its human development index by 42 per cent from 1980 to 2010. Likewise, Vietnam's high-technology exports increased from $0.9 billion in 1997 to $4 billion in 2010 while managing to reduce extreme poverty (people living on less than $1.25 a day, PPP) from 63.7 per cent of population in 1993 to 21.5 per cent in 2006.

Although many developing nations are just at the beginning of their route to build up effective science and technology systems with low publication record and patenting activity, more active approaches could be used to promote economic and social development. They have the distinct advantage of learning from the successes and failures of their peers and more progressive counterparts. If science is cool, doing the science of science policy right is even cooler. ■

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