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REVIEW

Scientific policies of developing countries and mid-level entry strategy: from the perspective of a marine scientist

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Abstract

Scientific developments are considered the primary source of the economic prosperity of a country. This faith in science appears stronger among economists and policymakers than those involved in day-to-day activities. However, science policy is often confused with a policy for science. The former is dictated by national interest and ideology, including long-term plans for the country. Because it is so crucial, whether to let scientists formulate the science policy of a nation is a long-standing issue in many countries. Policymakers and politicians generally provide the overall picture with some help from scientists. A common approach adopted by developing countries is the so-called 'mid-level entry strategy.' The idea is to dispense basic science to developed countries and focus on those areas that may bring immense profits. And when the time comes, and technology matures, bet heavily on those specific areas and jump ahead of the flock to reap the benefit. However, many consider DARPA (Defense Advanced Research Projects Agency) the most successful research and development (R&D) institution in the US. It is said that the accomplishment of the agency was possible because they started with basic science and moved up to applied and practical research. Doing so dominated the entire value chain, and the know-how was then disseminated to the public. Such observation leads one to conclude that, contrary to the myth of mid-level entry strategy, the real big reward for R&D of a country comes from starting at the fundamental level. On the other hand, because scientific and technological development is not straightforward, some examples may point to the contrary.

Keywords: Science policy, Basic science, Mid-level entry strategy, DARPA

Introduction

Science is considered the economic engine of a country. Science, technology (S&T), and education have been the driving force behind the recent rise of countries in Asia. The list includes Korea, which transformed from a developing country to a developed country. It changed from a recipient of international aid in the 60s and 70s to a donor country (MOST 1992). Many countries take Korea and China as recent examples of the power of science and technology. The government invested from early on in commercial technologies to manufacture steel, petrochemistry, automobile, and electronics, which eventually led to success in the global market.

People have long understood the importance of basic science as a source of knowledge and economic developments (Bush 1945; Brooks 1994 and references therein). Still, in the light of recent rapid successes in countries, like Korea and China, there is some doubt among policymakers and ordinary citizens of developing countries whether the investment in basic science really matters (e.g., Wong, Wong, 1996).

Are investments in basic science essential for developing countries trying to catch up? For one, scientific knowledge has no borders. Its impact is far reaching and extensive (Gibbons 1999). A breakthrough made in one country can be replicated by those in another, knowing it

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had worked earlier. Of course, there are regulations and institutions to protect intellectual properties so that original discoverers and investors would be recognized and reap the benefits. In practice, however, such a mechanism is not foolproof. There is no guarantee that the country invested in the basic sciences will reap the rewards.

It is well known that the development of science and technology is not necessarily linear from basic to applied science. According to Stokes (1997), the progress is complex and can go from basic to applied but also vice versa. From an investment point of view, a government can wait for the basic scientific results to become economically viable for perhaps five and maybe ten years, but not for 100 years. The emphasis on the quick return on investment appears to be increasing (Kjelstrup 2001). On the other hand, the way scientists conduct science has not changed. Basic science is important because scientists, like Faraday and Maxwell, in early nineteenth-century England fully understood electromagnetic phenomena that countries, like Korea could make and export all those electronic appliances, including modern-day semiconductors. Does basic science confer benefit to those countries that invested in it?

An idea that has slowly gained recognition among policymakers in Korea is the so-called 'Mid-Level Entry Strategy' made famous by one of the science ministers of Korea in the 90s (Jung and Lee 1996). Though a physicist, he maintained that Korea should not invest lavishly in basic science. He said Korea should leave that to developed countries, such as the United States, Japan, and Western Europe. Instead, government research and development (R&D) should focus on areas with the potential for significant economic returns shortly. We need to stay put on the sideline. But then, when the time comes, jump ahead among the rest of the countries by making significant investments, and become the leader.

There are strong arguments against such a proposition. Wong (1996) argued that a simple economic model where mass production by a low-wage workforce was the key to economic growth might not apply to emerging technologies, such as ICT and biotechnology. Modern information technology, for instance, began in the universities in the 80s. Many pharmaceutical and biotech companies are located in the most vibrant and popular cities, like Basel in Switzerland and San Diego in the US, where there is a supply of well-trained elites from the top universities. These cities' living costs are high but are offset by even higher salaries and good living conditions.

However, the problem is not straightforward. Wong (1996) mentioned that the situation in the developed countries is the shrinking investment in R&D, often in competition against the money for social welfare programs with the aging population. On the other hand, in developing countries, decisions are made top down and usually by those not well versed in science and technology, blinded by the faith that S&T will quickly turn into economic profit for the nation. The policymakers in developing countries tend to follow the latest trends, such as artificial intelligence and the fourth Industrial Revolution. Catchy buzzwords, like the carbon neutrality/hydrogen economy, thus appeal to them. What happens is that many significant investments get wasted, resulting in a low economic return. Like speculators of an asset, policymakers talk about 'what is the next big thing' as if it is a game of who gets there first. Occasionally there are some successes. However, the morale among scientists in such an environment in developing countries cannot be high because the way that science is done has not changed over the years. Moreover, it is certainly not a pretty education model to raise the next generation of scientists.

It is unclear how much the Korean government heeded the mid-level entry strategy. However, the system provided an ideological framework for policymakers in setting priorities in science and engineering. Many policymakers also took note of the 'Pasteur Quadrant' argument put forward by Stokes (1997), which explained the difference between pure basic science and applied practical research.

In this paper, I review science policy from a new perspective based on my experiences as a research scientist in marine geoscience at a government-supported institution (KORDI, presently KIOST) and as a university professor in Korea. Earth science seldom makes a national priority in Korea. There is a tendency to categorize it as basic science. An odd term, 'source or original technology,' was coined to include disciplines, like Earth science, that are at the border between basic and applied.

Many works of literature have reported on the role of basic science and its implementation within science policy in developed countries over the years (Neal et al. 2010 and references therein). However, far less is mentioned about what would be a good policy for the developing countries. The narrative I put forward is based on my experience as a marine scientist and may be different from that of others. However, the science policy of a country is an important matter and should be discussed openly by those involved in day-to-day practice and long-term management.

Science policy versus policy for science

It is said that the policy for science began with the famous open letter Vannevar Bush addressed to the President in 1945. In it, Bush, who during World War II headed the U.S. Office of Scientific Research and Development (OSRD), through which the wartime military R&D was carried out, including the development of radar and the nuclear bomb, emphasizes the importance of scientific research to national security and economic well-being. His efforts led to the creation of The National Research Council (NRC) and the National Research Foundation (NSF).

People often mistake science policy and policy for science. The former is set by the collective interest, usually the policymakers and government officials. It is about making the nation more robust and prosperous, related to national ideology as outlined in the 'Science—The Endless Frontier' (Bush 1945). On the other hand, the latter is much more accommodating to scientists as it talks about the well-being of individual scientists and issues, such as the fair distribution of research funding and support for graduate students. When we mention science policy, it is usually the policy for science we are referring to.

From the beginning, there was intense debate about whether to involve scientists in the discussion and making of science policy because it was too vital to the national interest. Another champion of science during this era following World War II was Harley Kilgore, a West Virginia Senator who constantly argued with Bush on whether to include scientists.

There are other cases where the personal conviction of scientists conflicted with the national interest. Many would have heard of the famous story of Robert Oppenheimer, the leader of the Manhattan Project. After months of anguish, Oppenheimer sided with the scientists who decided not to participate in the hydrogen bomb's development after seeing the damage caused by the earlier atomic bombs. His security license was revoked the next day, and he could not enter his office the next day. Also, at the beginning of the Human Genome Project in the 90s, biologists had apprehensions about whether their academic freedom would be restricted like those of earlier nuclear physicists. Many of you may have personal experience where your role as a scientist in the committee is to simply approve the plan that the government entirely designed. Again, this is because the government firmly believes that it is its role to set the national goals and schedule. Science is too important to let the scientists decide.

I often find it ironic that economists and policymakers appear to have greater faith in science than we scientists do. The reason is that scientific innovation in various forms accounts for 70–80% of GDP. In one study by Robert Solow, MIT economist and Nobel Laureate, who analyzed the US survey in which energy was data between 1909 in 1949, science accounts for >50% of national GDP and 87% of economic growth (the remainder being labor and capital) (Solow 1957). Such an urgency continues these days.

Because science is fundamental, many countries have a ministry-level agency called the Ministry of Science and Technology (MOST). In Korea, the names have changed depending on the government. ICT has been added as part of the MOST in the last ten years. However, it may surprise that MOST has no equivalency in the US. The Office of Science Technology and Planning (OSTP) in the White House has some 20 or so staff, but it is far from what other countries have. In the US, S&T is distributed among many agencies, including the Department of Defense (DoD), Department of Energy (DoE), NASA, NIH, and NSF, to name a few. It is decentralized.

The research by outside entities is referred to as extramural (e.g., NSF). Those conducting internal research are called intramural (e.g., USGS under the Department of Interior and NOAA under the Department of Commerce). NIH and NASA are both intramural and extramural. The extramural projects generally fund academic communities.

In Korea, the MOST is supposed to act as the control tower for all S&T. However, in practice, different ministries have their budgets and run R&D. So, in a way, it is a hybrid system. Attempts have been made to centralize all S&T under the MOST such that investment in resources is not duplicated. However, the efforts have failed miserably because no ministry wants to give up its R&D. A compromise was reached where the MOST is in charge of the basic S&T and other mission-oriented ministries of applied S&T. However, the MOST, in reality, is very selective on the science it considers as basic. Small but merit-based support for basic science comes from the National Research Foundation (NRF), equivalent to NSF in the US. Unfortunately, the MOST itself has turned into a mission-oriented agency focusing on items the administration deems important and fashionable over the years.

In my area of ocean science, the Ministry of Oceans and Fisheries (MOF) was established in the 90s to collectively handle all marine-related affairs, including maritime affairs and port management, fisheries, and S&T. The problem, however, is that a clear-cut division between the basic and applied is not possible. NRF does not support many marine research projects requiring extensive infrastructure, such as research vessels because they are too expensive. Until recently, only government-supported institutions under MOF were given enough money to run the ship for their research.

Like many countries, competition and rivalry exist among government agencies in Korea. When approached with a basic marine scientific proposal (such as the International Ocean Drilling Program), the MOST will gently refuse, claiming that it belongs to MOF. On the other hand, MOF will say that because it is basic science, MOST should handle it. Since the launch of MOF, the overall amount of R&D has increased tremendously in the last 30 years. The biggest benefactors have been the government-supported institutions.

DARPA

The recent book 'Beyond Sputnik' is a detailed account of the US S&T from 1945 to 2008 (Neal et al. 2008). In the era immediately following the war, the policymakers debated but did treat science seriously until 1957. The US panicked at the technological superiority of the USSR with the launch of Sputnik. People in the US still talk about the Sputnik moment and the turn of events that led to the progressive development of science and technologies.

According to Neal and others, US government officials generally consider DARPA (Defense Advanced Research Projects Agency) the most successful government institute in R&D; DARPA was responsible for developing, among many groundbreaking developments, the Internet, GPS, and laser. Because it was so successful, there were talks about making Energy ARPA in the 70s.

One of the important reasons why DARPA was so successful is that it started from basic science, then moved to applied science, and further to the top, monopolized the entire value chain of knowledge. Many of the results were then passed to the public for widespread commercial use. According to the famous 6.x R&D schematic of DARPA, scientists at each step are not told what those at other levels are doing. Their job is to report their scientific findings effectively without bias. This differs from practices in Korea and perhaps in other developing countries.

In DARPA, for instance, the research steps are systematically divided: 6.1 (basic), 6.2 (applied), 6.3 (advanced technology development), … and 6.6 & 6.7 (weapons testing & evaluation). Again the key is R&D done from basic science, and the scientist's job is to report the scientific findings without trying to over-justify the significance of their results. Then the scientists or engineers at the next level will consider the finding together with all other scientific developments and produce a new weapon system in the case of DARPA.

The essence of the DARPA system is its multilevel approach and its independence. The scientist at 6.1 does not know what the scientists at 6.2 or above are doing, including whether they are using the findings that 6.1 made. A complete guarantee of scientific integrity can be achieved. The taxpayer's money is correctly spent on the mission, whatever that it is.

The DARPA system contrasts with projects in Korea because the scientist in Korea has to constantly cater to the government official who decides the project. Tweaking the outcome such that the funding agency can claim the investment was a success cannot be prevented. Self-promotion sometimes exaggerated is unavoidable. Suppose one comes short of fulfilling the intended target (which includes meeting practical goals and producing a certain number of papers or a paper in a very reputable international journal). In that case, that person will receive a disadvantage and be considered a disappointment in their organization.

Furthermore, due to a lack of expertise, the actual achievement of the project is only evaluated in some metric systems. As a result, true qualitative successes and contributions can be missed. These practices lead to the waste of taxpayers' money.

Wong (1996) warned about such inefficiency in developing countries. Even though developing countries spend a higher percentage of their GDP on S&T, the success rate in governmental R&D is much lower compared to developed countries. Another problem is that there is no accountability. By the time a government official gains some understanding, the person is rotated to another post for fear that being posted at one position too long would result in corruption.

Such blatant corruption seldom occurs in Korea. The selection and evaluation systems have become transparent and objective. However, a lack of understanding or a superficial understanding of the government officials can be a problem. It is not easy to find government officials who understand the science of an area they are in charge of. The system tries to involve more scientists in the evaluation of the research. However, finding the right expertise is problematic in many small developing countries. As a result, many top-level decisions, including which none area to focus are being made by nonexpert policymakers and politicians.

Despite the difficulties, scientists in developing countries must get involved in science policy and voice their opinions. Once in a while, an opportunity comes where a scientist can change the practice. For me, this chance occurred in 2014 (Zastrow 2015). My testimony under oath at the National Assembly led to a new law and sweeping change, which allows the sharing of expensive research vessels for global ocean investigation with academia. In 2017, a shared use committee was formed that enables access to the global ocean research vessels to the academic community and industry (Lee 2022).

A sad but crucial downturn of DARPA is that, unlike the good old days of the Cold War and national security when sufficient funds were available, the agency had to compete against other institutions. In the 70s, the critical national priority was energy. In the 90s, the well-being and health of the aging baby boomers became the national priority. In 2000, anti-terror and security became an important issue. This decade seems to be about global climate concerns and meeting the ESG (environmental, social, and governance) criteria.

According to Neal et al. (2008), US policymakers share the importance of basic science. They understand well that to win big, one has to invest starting from the fundamental science. But with a shrinking budget and an ever-growing number of new areas, even DARPA cannot sustain its old system. They are asked to attend to imminent societal problems. Visibility is vital in this age of information and media. There is no longer a grand vision to advance S&T. They understand that the big prize of scientific development may not be realized in this way alone. However, a shrinking budget is inevitable.

Concluding remarks

The development of S&T is considered the most important means to address societal problems and bring prosperity to a country. Because science is deemed too important for scientists to handle, the government makes vital decisions such as setting priorities and designing which area to invest in. As a result, genuine policies to promote science (policy for science as opposed to science policy) are often neglected.

An idea for developing countries may be a mid-level entry strategy where the basic science is left for developed countries. The attention is given to those areas considered an enormous commercial success. However, future technologies, including ICT and biotechnology, require a solid basic science and education investment. This is contradictory to the standard mid-level entry strategy model.

The most successful government institution is DARPA. The agency's accomplishments stem from a unique R&D system maintained over the years. The projects started from the basic science level. It then goes up to a more applied level and eventually develops a new weapon system, including evaluation and testing. The critical point of this R&D scheme is that the research at each level is conducted independently; thus, there are no attempts to exaggerate the outcome. Scientific integrity and ethical conduct are guaranteed.

Creating a system that guarantees ethical conduct is vital in developing countries. Mismanagement and inefficiency may result when nonexpert policymakers and politicians make the important decisions. Science is a contract with society (Gibbons 1999). For the outcome to be transparent and reliable, the involvement of scientists in the initial design of scientific policy may be necessary.

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