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S&T IN THE PHILIPPINES: DIRECTIONS IN THE 21ST CENTURY*

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1. Introduction

The competitiveness of firms and the sustainable development of nations in the 21st century will depend largely on the dynamism of their technological innovation systems. Considering the furious pace of discoveries in the sciences and the diminishing gap between scientific discovery and technological application, firms and nations must actively participate in developments in these areas. Firms and nations must also manage their technological resources, as well as (or perhaps better than) their other resources (such as natural resources, labor and capital), because knowledge has become the principal source of wealth today and will be more so in the future. This means that when nations and firms consider their long-term futures, whether from the strategic planning or strategic development perspective, they will have to do technology planning.

Technology planning, like any type of planning, requires a reasonably good "guess" or forecast of the future in order to be useful. Technology forecasting is the process of projecting the future of a technology starting from its present state (as measured by its capability, use and acceptance), to advances in its basic science

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* Summary of the NEDA-LTPRDP research project submitted by the Technology Management Foundation to the National Economic Development Authority in October 1997. Some recent developments are added to make the report current.

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foundation. The forecast considers as well the entire gamut of social, cultural, economic and political forces in a society that shape or affect technological developments.

Technology forecasts are useful at different levels. At the macro level, an excellent technology forecast can help the leadership of a country map out areas for investment (what basic industries and manufacturing to develop, which areas in agriculture to concentrate on); the corresponding human resources, organizations, and infrastructure needed for investment and industry development; and the strategies for the application of technology (mode of technology acquisition and the role of the public and private sectors).

At the firm level, technology forecasting can help managers make intelligent decisions regarding technology purchases (the right price to pay and when to change equipment, processes and software); technology development (what technology to develop in-house and what to acquire as well as the best arrangement for acquiring the technology); and the overall target level of the firm's technological capability (whether operative, adaptive, replicative, innovative or creative). For nations and firms, therefore, technology forecasts can suggest possible economic and business opportunities arising from scientific and technological developments (Magpantay, 1999).

If the forecast of technologies provides us with a glimpse of the future, the assessment of the present state of our science and technology not only reflects the initial state on which we will build, but also our capability in achieving the desired future. An accurate assessment of the present state of science and technology is imperative if the long-term plan is to have a reasonable chance of success. Otherwise, we will just be building castles in the air and might as well not make any plans at all.

An accurate assessment of the present state of science and technology of the country requires fact-based analysis. At the very least, we must have accurate data on the capability of institutions, expenditures on R&D by the private and public sectors, number of human resources (scientists, engineers and technicians) and publications, patents and technological innovations produced in the country. Unfortunately, much of the data is not reliable. We do not even accurately count the few Ph.Ds in some fields or the total number of graduates in some science degree programs, and we can only roughly guess the private sector's expenditures on R&D.

We must also understand the root cause of our underdevelopment and the low level of science and technology in the country. Fairly well discussed, understanding this problem explains why it is difficult for us to seriously commit to programs we need to break the cycle of underdevelopment and backward S&T. An analysis of the problem also explains why we do not have reliable data on S&T.

Given the present backward state of science and technology and the glaring weaknesses in our economic sectors, do we have what it takes to learn and be competitive in the advanced technology areas in the next 25 years? This question can be answered from different perspectives. From the point of view of learning and being able to contribute to these areas, perhaps even becoming the leader in some of them, the answer is yes. Advanced technology areas are based on the modern sciences, which are easily accessible through journals, conferences, seminars and university lectures. Thus, unless there is something in our genetic make-up that says we cannot learn the modern sciences, there is no reason why we cannot understand and eventually compete in the advanced technologies.

The experiences of Korea and Taiwan show that 25 years is more than sufficient to build up the modern science foundation and learn the advanced technologies. The timetable for achieving success can even be shorter as the recent success of Bangalore, India in information technology shows. These three countries have a strong program in the basic sciences and actively participate in developing high technologies, which are presently dominated by the United States, Japan and Western Europe.

As to whether or not we should learn the advanced technologies, we do not have much of a choice unless, of course, we are willing to retain our present role in the international division of labor as a viable future for our children. As I argued later in this paper, we will see a spiraling development in S&T and if we do not participate in its development today, then the knowledge gaps and economic competitiveness we have to overcome will just keep on widening. In short, we really do not have a choice.

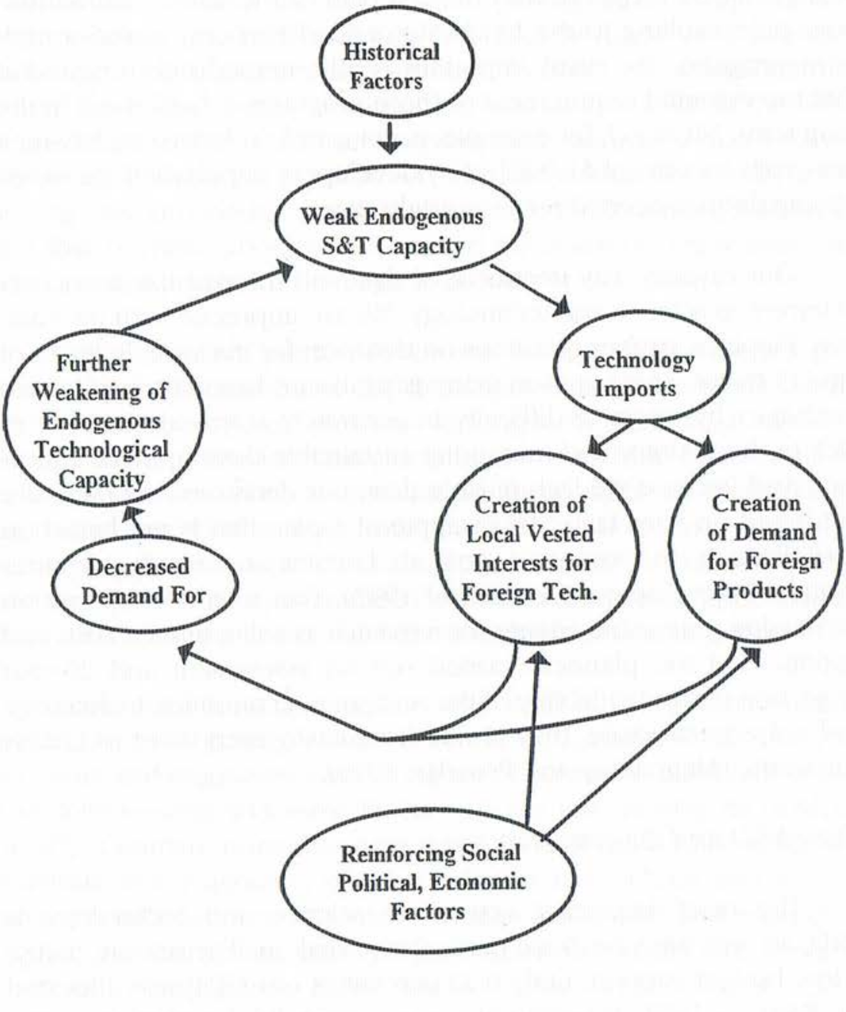
2. Summary of the Present State of the Country's S&T

The country's science and technology today is backward and cannot make us competitive in the world market in the 21st century. All our economic sectors—agriculture, manufacturing and services—do not produce but merely consume technologies they can afford which are generally not state-of-the-art. How this came to be is explained by Roque and Posadas' (1986) theory of the "vicious circle of technological dependence and backwardness" (see Figure 1). This theory, however, only considers the reinforcing social, political and economic factors that have kept the country underdeveloped. It fails to take into account the cultural factors that hinder us from undertaking serious interventions in S&T, which we need in order to break the vicious cycle.

Cultural factors that affect S&T

What are these cultural factors? The government campaign on TV to develop the culture of doing things right confirms the prevailing attitude of "puwede na yan." Internalized as a culture of "making do," this attitude not only explains why our infrastructure projects are substandard and why many of our products do not pass the stringent quality control abroad, but also why we find it difficult to perform well in the sciences. Doing well in the sciences requires not only brilliance but above all, hard-work, dedication and tenacity, i.e., not letting go of a problem until it is fully understood.

Figure 1 - The Vicious Circle of Technological Dependence and Backwardness



Source: Roque and Posadas, 1986.

Another cultural factor is the premium we put on the short- rather than the long-term. This is reflected in the "get rich quick" attitude, often the charge made against our business sector. But the public sector is equally guilty. Our post-war development programs were all mid-term plans (4 to 6 years). Philippines 2000 is an eight-year NIChood program. And the last plan of the Ramos administration, pole vaulting to the high value added services, is also a mid-term program. We want important results immediately unmindful that the essential requirement of these programs is hard work in the long term. NIChood, for example, is not simply achieved by having a per capita income of $1,000 but by developing important technological capabilities needed for industrialization.

Our cavalier way treatment of data and information is another deterrent to science and technology. We are imprecise with information. Filipinos answer questions on distance, for instance, in terms of time of travel. There are too many gaps in our data gathering, which explains why we have difficulty in accurately assessing the state of S&T in the country and measuring sustainable development indicators. And because we lack reliable data, our decisions and plans are not based on hard facts. An example of a plan that is not based on hard facts is the country's goal to become an energy exporter (National Development Summit of 1997). This plan is anchored on harnessing renewable energy sources such as solar, wind, OTEC and riptide. Had the planners carried out an assessment and 20-year projection of the availability of the resources, economics, technology and industry structure, they would have easily seen that this goal is unrealistic (Magpantay and Posadas, 1998).

Weak R&D and the private sector

The most important activity in science and technology is R&D, an area we have been particularly weak in. The reason, partly, is low budget support. Only 0.22 percent of our GDP was allocated for R&D in 1992, for example. Also, most R&D activities in the country are undertaken by the public sector and very badly at that.

The question now is why the private sector is not particularly interested in doing R&D. There may be historical reasons. Our colonial and neo-colonial past resulted in a weak industrial base and low level of manufacturing, precisely the economic sectors that are R&D-intensive. But this explanation is not sufficient because even in areas where we are relatively strong, such as agriculture and medicine, our R&D activities are grossly inadequate as measured by such indicators as publication output. Most agricultural researches in the country, for instance, are done by IRRI. In the field of medicine, majority of our hospitals and medical schools focus almost exclusively on medical services and education, hardly producing new knowledge owing to the lack of Ph.Ds among MDs. It is rare that hospital laboratories are used for research. There must be other reasons, then, for the neglect of R&D in the country.

Cultural factors partly provide the answer. R&D requires patience since the time frame for development is short- to mid-term while research requires medium- to long-term. R&D also involves taking risks because R&D may or may not bear fruit. Most of all, it calls for full commitment not just in form, such as establishing centers of excellence, but more importantly in essence, by fully supporting these centers. Our culture, unfortunately, shows a preference for quick results, guaranteed returns and image or appearance. With such a culture, R&D will have a difficult time taking root.

Some hard facts also explain why R&D in the country is very weak. The most glaring statistic is that in 1992, out of 9,960 research scientists and engineers—including social scientists and those in the humanities—only 943 were Ph.Ds and the rest, mostly BS holders (6,087). Compare ourselves with Korea, which has a total of 88,764 scientists and engineers, of whom 22,484 have Ph.Ds and 25,717 have master's degrees. In terms of research scientists and engineers (RSEs), the Philippines has 138 per million of population, in stark contrast to Singapore's 2,800, Korea's 3,300, and Taiwan's 4,300. Considering, further, that very few tertiary institutions in our country offer quality science and engineering undergraduate degree programs, our neighbors surpass us not only in number but also in quality.

The state of science and mathematics education

The teaching of science and mathematics at the primary level is hampered by the language policy, which dictates the teaching of these subjects in English. Since the overwhelming majority of our students do not speak English at home, and most of their teachers are not fluent in English either, the students end up speaking bad English and not learning science and mathematics. More importantly, the students do not identify science and mathematics with our culture in daily life.

Aside from the language policy, the teaching of science and mathematics at the basic levels also suffers because of poor facilities. Very few schools, mostly private, are able to provide even the rudimentary laboratory for an effective science education. And according to the Institute for Science and Mathematics Education (ISMED) of the University of the Philippines, "many teachers at all levels do not have the content background required to teach the subjects they are teaching." The survey of high school science and mathematics teachers done in 1992 shows that 71 percent of math, 40 percent of general science, 41 percent of biology, 21 percent of chemistry and 8 percent of physics teachers are qualified to teach their subjects (i.e., they took the preparatory courses in college). Note that as the field of science becomes more fundamental, the less qualified most of the teachers become. It is not surprising then that physics receives the lowest enrollment at the tertiary level. High school physics must have been a traumatic experience for most students.

Taking all these factors together, one can see why our students do not do well in international science and mathematics tests. In the Second International Science Study (1988), our 14-year olds and 10-year olds performed much lower than children from countries like

Hongkong, Singapore, Korea and Japan. Our school children's performance is second to the last, 16th out of 17. More recently, in the Third International Mathematics and Science study (1996), our 13-year olds ranked 37th out of 39 in mathematics and 40th out of 41 in science.

This situation is alarming! The 21st century is a period of advanced technology and global free trade and we are not preparing our children for it. Unless we act and act decisively, children will become the domestic helpers, laborers and entertainers of the world just like their parents today. Surely our present role in the international division of labor is one thing we do not want to bequeath to our children.

But what is our response to this problem? At the level of the overall national plan (National Development Summit), the country's response is to become the knowledge center in the Asia-Pacific region in ten years or less!

Let us see what the others are doing. The US, which has the most advanced science and technology in the world, recognizes that their basic science education, on average, is declining. This worries them despite the considerable number of bright students being educated in schools or programs for the gifted. (It is not unusual for universities to offer advanced courses like calculus to junior high or even elementary students.) Thus the federal government, the local government and school boards, with the help of foundations and philanthropists, are creating new and innovative educational systems. High school physics teachers in the American midwest attend enrichment classes at Fermi Laboratory during the summer. More fundamentally, high school teachers have a first degree in physics at least and some even have master's degrees. In Japan, for example, it is not unusual for high school teachers to acquire Ph.Ds.

But the most high profile contribution to solving the problem of education is the endowment of $500 million by a businessman (his name escapes the writer at the moment) in 1992 and Bill Gates' educational endowment for minorities in 1999. These acts are not uncommon in the US, where many universities were established by donations of philanthropists. Unfortunately, no such practice prevails here.

At the Philippine tertiary level, colleges and universities proliferate. State universities and colleges alone number about 100 and there are 1,034 private tertiary institutions. In 1996, the total enrolment was about 2,018,000 and graduates numbered around 204,000 (data supplied by Commission on HIgher Education [CHED]). The strong preference of Filipinos for "white collar" jobs provides tertiary institutions a big market. But most of these institutions are mediocre and hardly deserve to be called a university. Hence there is a need to reform the tertiary educational system in the country.

The reform should begin with the faculty. After all, the strength and reputation of a university are determined by the quality of its faculty. In credible universities abroad, nearly all the faculty have Ph.Ds for it is their primary entry requirement, the Ph.D. being a research degree. (The few exceptions exhibit an unusually high standard of scholarship as reflected in their publications.) The second requirement is post-doctoral experience because it hones and sharpens the knowledge generation skills of a fresh Ph.D. It is also during post-doctoral work that an academic generally develops his/her first field of expertise (academics generally do not stay in a particular area until the end of their careers). The third requirement is to publish because the young Ph.D. must be able to contribute to the body of knowledge.

Unfortunately, several factors hinder the adoption of this policy and practice in our tertiary institutions. First, generally, parents believe their children's education end with a BS/BA degree and expect their children to earn a living after getting their diploma. Second, the teaching profession is no longer prestigious because of the low salary and the lack of importance given to the institution by the government. (In Germany, a C4 Professor is the most respected member of the community, not politicians nor medical doctors.)

Because of this, we generally do not attract the brightest students to the academe. Instead they go elsewhere, to high paying professions and careers. Third, we still do not have a culture of scholarship and research as shown by our very low number of publications (more on this later).

Because of these reasons, the percentage of Ph.D. faculty members in all tertiary institutions is low. Even in the University of the Philippines, which ranked 32 in last year's *Asiaweek* survey of Asian universities, only 25 percent of its faculty have Ph.Ds. In the College of Science and the College of Engineering (COE) in Diliman, 51 percent and 25 percent of their respective faculties have Ph.Ds. With the exception of a few like Ateneo, De la Salle, Santo Tomas and Mindanao State in Iligan, the other universities and colleges have first degree holders in their science and engineering departments.

With a mediocre faculty profile and ill-equipped laboratory facilities, many of these tertiary institutions are not capable of offering quality undergraduate programs in the sciences and engineering. The effect of our substandard engineering education is that we produce many under-trained graduates who end up doing low paying technical work here and abroad instead of becoming engineers in the true sense of the profession. As for the graduates of UP Diliman and a few more schools, they mostly end up in management positions (eventually taking MBA) while a select few go to engineering graduate schools.

The extremely low enrollment in engineering graduate schools is a direct consequence of the substandard undergraduate programs. According to former Dean Vea of UP COE, less than 1 percent of the country's engineering graduates go to graduate school, which is much lower than in Singapore, Japan, Taiwan, and Malaysia. At the graduate level, the problem is that only UP Diliman offers a master's program comparable to that offered by our neighbors. But for the Ph.D. degree, not even UP Diliman can offer a competitive program because of very little research activity. The reason for this, aside from the cultural factors cited earlier, is the low compensation (salary is tied to SSL) which forces faculty members to do outside consulting work.

Flor Lacanilao of the Marine Sciences Institute of UP Diliman scrutinized the performance of the University's premiere unit, the College of Science (CS). He found that although CS has the highest number of publications in refereed, international journals—27 out of the UP System's 60 and the entire country's 131 publications in 1995—CS nonetheless pales in comparison with the National University of Singapore (NUS). In 1994, for instance, the science departments of NUS, with a Ph.D. faculty of 154, published 389 papers in international journals or an average of 2.53 papers per Ph.D. CS, on the other hand, with a Ph.D. faculty of 101, only managed to produce 24 international publications or an average of 0.21 paper per Ph.D.

More bothersome is that the productivity of CS' Ph.D. faculty has been decreasing through the years, averaging 0.30 in 1985-87, 0.31 in 1988-1990, and 0.24 in 1991-1993. What is the cause of this already low productivity still declining further? The profile of the CS faculty shows that 35 of the 127 Ph.Ds (28 percent) received their degrees between 1990 and 1997, while an additional 20 received theirs during the 1980s. This means that a high number of the CS faculty (55 of 127 or 43 percent) received their degrees in UP. In many institutions abroad, this would be cause for concern because of the danger of in-breeding. Hiring one's own graduates is not healthy because no new ideas are injected into the academic departments.

But in the University of the Philippines, in-breeding cannot be avoided because of the lack of opportunities to study abroad. Many junior faculty members (and some are already tenured even before getting their Ph.D.) opt to study locally, mainly at UP because it is the premiere institution of the country. Since we already have this situation, the only recourse to avoid stagnation of ideas is to send all local graduates for at least two years post-doctoral experience abroad. But UP does not have any money for this activity. The Engineering and Science Education Program (ESEP) should have been the venue for this advanced manpower training program. But the program managers of ESEP skimped on the money, providing stipends, which were lower than student assistant rates, and shortening the post-doctoral stint to 6 months.

With so many recent Ph.D. graduates, our international publications would have increased tremendously had we required international journal publications for graduation. But most Ph.D. programs do not impose this requirement. A pre-print at best or just a bound copy of a thesis accepted by a local panel of examiners will do. But having publications based on Ph.D. work is not only the responsibility of the student. It is primarily the responsibility of the adviser because the student, after all, just hangs by the adviser's coat tails. If the adviser, too, does not publish because the university's tenure and promotion policies are too lax (faculty can easily earn points by just attending and presenting papers in conferences, publishing in in-house journals or other local journals, serving in various committees in the university, etc.), then the student will most likely graduate without a single publication. Given the cultural factors that discourage research, there is greater reason for the University to put a premium on international publications.

Fortunately, the new president of the University of the Philippines, Dr. Francisco Nemenzo Jr., understands the importance of doing research and publishing in ISI journals, activities where the University is particularly weak. A few months in office, he launched two programs (Academic Distinction Awards and Creative and Research Scholarship Grants) that encourage international publications and creative/research work. The programs provide funds for research and creative work much higher than the typical P3,000.00 per month honorarium allowed by COA. In addition to this, ISI journal publications and books (refereed) published by internationally renowned publishing houses are also granted a considerable cash award. Dr. Nemenzo also made the long-delayed Scientific Career

System part of the UP Academic Distinction Award. Through consistent scientific productivity, scientists can now pursue a professional scientist development track parallel to the administrative track, which is usually taken by senior scientists to advance their careers. Moreover, promising recent Ph.Ds (within the past three years) will be given the opportunity to hone their research expertise through a post-doctoral grant in the best research laboratory abroad.

These programs will go a long way in establishing a research tradition and a culture of excellence in the University of the Philippines. It is ironic that it took a Marxist, who was expected to be an exponent of absolute equity, to arrest the decline in the University's academic reputation and put it back on the path of academic excellence. Hopefully this experiment will be adopted by the other tertiary institutions in the country.

3. Prioritizing the Advanced Technology Areas

The most important capability in the 21st century is flexibility, the ability to respond positively to developments in a fast changing world. If Japan overtook the US in manufacturing in fewer than four decades with technologies based on automation, simple and inflexible robots, and fourth generation computers, the game for economic dominance certainly looks wide open for all countries that have the capability in the advanced technologies. The reasons for this are:

- Advanced technologies, which are based on the modern sciences, enable people to do excellent science, which in turn leads to new and better technologies.

- Advanced technologies improve the efficiency, raise the productivity and alleviate/mitigate the environmental consequences of Second Wave industries. Such improvements, in turn, will sustain our development.

- Advanced technologies enable societies to utilize most resources of planet earth efficiently (wind, geothermal, ocean's heat for energy; extracting the minute rare earth metals in ores for use in optical fibers and superconductors; genetic inventory of all the flora and fauna for future use in pharmaceutical and biochemical purposes, etc.). In other words, without the advanced technologies, many minerals and other resources would have remained unused.

- Advanced technologies will enable trained personnel to design, synthesize, fabricate and create new materials for specific purposes from their atomic and molecular building blocks.

- Advanced technologies enhance, amplify the intelligence of human beings, making them more capable of dealing with the first four concerns. In turn, an accelerated, spiraling development of S&T is expected, which we may not fully comprehend right away. Fortunately, all these developments will enable people to have more time to spend on the humanities and the arts (working hours will be reduced because of robotics, computers, etc.)—the very areas that will provide the balance, insight and perspective on how to handle the fast changes in the future.

We therefore need to develop capabilities in the advanced technology areas if we want to become a nation that will: (1) contribute to the pool of knowledge; (2) attain sustainable development; and (3) at least be competitive in some high-value-added economic activity.

This point of view finds little value in Schumacher's notion of appropriate technology. All countries that emphasized appropriate technology for their development program remained underdeveloped. Neither does this viewpoint consider Second Wave technologies (based on the classical sciences) *per se* because they are focused on processes and products that, despite their importance in the future (textiles, electricity, cement, paper, etc.), depend on the application of advanced technologies for their competitiveness. Besides, targeting Second Wave technologies when the future lies in the advanced technologies is, to paraphrase the TV show "Future Quest," like "spending the rest of our lives in the past."

Ideally, the country should go into all the advanced technology areas as early as possible (one to five years). Realistically, this cannot be done for the simple reason that we lack resources, human and financial. Thus there is need to evaluate the advanced technologies to determine the areas we should immediately go into and at what level we participate in its R&D (academic research, product development, collaborative research between the public and private sectors). However, it must be emphasized that in about six to ten years, we should have established active R&D programs undertaken by both the public and private sectors in all the advanced technology areas.

The advanced technology areas the Philippines can engage in are microelectronics, photonics, materials science, robotics and artificial intelligence, micromachines and nanotechnology, genetic engineering, and information technlogy. These technologies were evaluated by considering their impact on (1) Second Wave industries, (2) food production, (3) provision of health care, (4) education, (5) other aspects of the production process (flexible manufacturing, just-in-time) and delivery of goods and services, and (6) environment and ecology. Two other factors were used to evaluating these technologies: human resource requirement and economic cost/benefit.

The evaluation procedure most useful in a complex decision-making situation is the Analytic Hierarchy procedure (Porter, et al., 1991). Employing this procedure, the technologies that came out with the highest weights, that is, those most relevant to the country and most likely to yield economic success in the short to mid term, are *materials science, information technology, genetic engineering and microelectronics* (Magpantay, et al., 1997a).

4. Recommendations

To enter these fields of advanced technology, certain policy changes are required in such areas as government planning and finance, technology evaluation, education, and the promotion of S&T.

Planning, budgeting and finance

The public sector should experiment with a rational planning and allocation process. If implemented, the S&T sector will have to draft realistic, feasible programs because they are guaranteed the funds. This is much better than the present practice where government planners make any plan, even if not viable, because they are not sure how much they will get anyway (if they are lucky enough, that is, to get a budget that is bigger than their operating expenses). One solution to this problem was proposed by then Senator Orlando Mercado, which mandated that our R&D expenditure (in terms of percentage of GDP) should be comparable to those of other countries. This is, however, not realistic because the S&T sector will not be able to absorb the funds anyway in the first few years. Worse, the money might end up a source of corruption, making the S&T sector less popular than it already is.

Besides, how should this proposal be justified before the legislature? What makes the S&T sector so special that it must be afforded special treatment in the budget process? There are three approaches to this problem. One is for the executive to use its influence with legislators to arrive at a modus vivendi that will effectively facilitate the R&D budget request of the DOST and other agencies. However, considering the nature of checks and balances in our democratic (and still feudal) system, there is bound to be a legislator who will throw a monkey wrench at this approach.

The second solution is to raise the proposal to the level of a law. But this will be debated endlessly in Congress and well-meaning people will raise the valid question of planning rationally solely for the sciences. On the other hand, if rational planning were done for all, government would have to do the nightmarish zero-based budgeting. Again, the needed reform in the S&T sector will get bogged down.

The third solution is to adopt the practice of having a guaranteed development budget at the start of every mid-term development plan as is practiced in Malaysia. This means that if the development programs of an agency are accepted in the mid-term plan, then that agency will receive its usual allocation (determined historically plus the usual additions for inflation) and an additional budget to implement the development programs. When these programs are regularized in the agency's operation, the development allocation then gets incorporated into the usual budget. The agency again proposes another set of programs for the next mid-term plan and the cycle is continued.

This third solution has a better chance of succeeding than the other two. It is rational, it will not open a can of worms, and everybody has a chance to put in his development programs. For the science and technology sector to benefit from this arrangement, the DOST secretary must be a fighter and must have the support of the President.

The next policy recommendation is for the country to target the four advanced technology areas (*microelectronics, materials science, information technology and genetic engineering*) for immediate development. The requirements would be human resource development, R&D in the universities, establishment of SMEs inside S&T Parks, and encouragement of the private sector to put up large-scale business ventures that will make extensive use of these technologies.

In terms of R&D and human resource development, the Department of Science and Technology (DOST) should define specific areas the Universities should get into not only in the four advanced technologies but also in photonics, robotics/AI and micromachines. The DOST should do this by funding institutions (centers of excellence and even the science and engineering departments of private schools) rather than wait for proposals from individual scientists. If R&D support is guaranteed for five years, then these institutions can consistently work on these areas for an extended period, which will enable them to develop expertise and maybe find niche applications.

In fewer than ten years, the private sector will compete in an almost open global market (uniform tariff at 4 percent), and in a completely open global market in less than 20 years time. The local industries must plan for these two events by drafting their strategic business plans (SBPs). Just like the SBPs of most competitive firms in the world today, the SBPs of our local firms should include a technology plan. This means our local firms must learn and start practicing activities such as technology assessment and technology forecasting (Magpantay, et al., 1997b).

More important is research and development. Local firms or, at least, industry groups must start doing and internalizing R&D. If the firms and industries allocate money for ads and marketing, they must also regularly allocate money for R&D (see programs for a specific mechanism). If local industries do not learn to do R&D, then they will not survive the competition in the second decade of the 21st century.

The role of the public sector in these private sector activities can be interventionist or supportive. If interventionist, the government will require through legislation the collection of an R&D tax from all firms to finance the operation of R&D institutes that cater to industry needs. Exemptions from this tax will only be given to industries or firms that put up their own R&D units.

If supportive, the government will provide incentives or support facilities for R&D. Government, through the Industry Development Council, can try to convince the private sector that it is to their best interest to prepare for the competition in the 21st century. But whether the private sector responds or not is its own lookout.

Which approach is better? Taiwan employed the interventionist role and judging from its current economic condition, its approach has worked. But the interventionist solution is not consistent with present trends in our society. Hence we should first experiment with the supportive role. If the private sector still does not respond positively say in five years time (2003), then the government can either let it go and live with our role in the international division of labor, or adopt the interventionist role.

Evaluation

The very first thing we must do is clean up the data of CHED, DOST and other government agencies. In general the evaluation of technologies is not properly done because of the unreliability of data supplied by these agencies. Next, we should develop indicator-based assessment procedures plotted along time series plots so that we can at least do trend extrapolation (business as usual).

The evaluation procedure to be developed must be able to relate the performance of the S&T sector to that of the entire economy. This way, policy makers and our leaders will have a clear understanding of the role of S&T in development rather than just a vague motherhood view of S&T as part of the common good.

For the public sector, the provision of five-year R&D support for institutions rather than individual scientists will simplify the monitoring/evaluation procedures of projects. Today, the evaluation/monitoring is done quarterly by DOST Councils whose personnel who do not understand the project. They visit project proponents and gather data not relevant to the success of the project. And since the release of project funds is often delayed, proponents are bothered by repeated questions regarding the current status of their research.

In the new funding scheme, the DOST will define the areas they want to develop and their expectations (minimum number of publications and/or patents, new products and processes, technologies transferred to the private sector). For its part the R&D institution will have some leeway on how to implement the project. Monitoring in this case will be done once a year (institute submits a progress report) and a serious evaluation will be carried out by a group of experts towards the end to find out if the project is successful, needs an extension or is better undertaken by another institution.

For tertiary institutions, the system of accreditation must be started. This is the best way to guarantee the quality of our university education. As for the private sector, benchmarking should be institutionalized. This is a good way to encourage local industries not only to be competitive but also to engage in R&D.

Coordination

There are enough S&T-related coordinating bodies that link the public, academe and private sectors, namely: the Science and Technology Coordinating Council (STTC), Human Development Council (HDC), Eminent Persons Group (EPG), NEDA's Technical Working Group (TWG), and Board of Investments (BOI's) Industry Development Council (IDC). The EPG and TWG are *ad hoc* bodies while the STCC (created by President Aquino), the IDC and HDC (created by President Ramos) are permanent, having the force of a law or presidential support. (HDC was created by a Republic Act, STCC by an Administrative Order, and IDC by an Executive Order.) There is therefore no need to create new agencies (lest we become over-coordinated).

As for environmental concerns, the country's commitment to Agenda 21 through the Philippine Council for Sustainable Development is a good start. We should be able to attract more environmental NGOs/POs to participate in the country's environment and ecology programs. The government, through the DENR and

DOST, should upgrade the NGOs/POs scientific and technical know-how so that misunderstandings due to misconceptions of science are minimized.

S&T promotion

We should come out with a policy paper on S&T promotion as mandated by the Constitutional provision on S&T, which says: "The state shall encourage the widest participation of private groups, local governments, and community-based organizations in the generation and utilization of science and technology." The policy paper should emphasize the promotion of S&T at the grassroots level. For example, it should guide activities like the creation of science TV programs; the translation or dubbing into Filipino of foreign programs like "Future Quest," "Discovery," Newton's Apple;" the use of the Agila satellite to broadcast S&T programs to benefit schools in far-flung rural and upland communities; and the setting up of a mobile science exploratorium to go around the country all year round.

Equally important is the development of a technology orientation among Filipino entrepreneurs and top management. If our business leaders have a technology orientation, then the private sector will do R&D and undertake technology planning. At this time, it is not clear to the author what policy instrument to employ to promote a technology orientation in the business sector.

Education

The country should come out with a policy statement that basic science and mathematics should be taught in the dialect of the region. These subjects can then be taught as early as grade one. The shift to English should only be done when students have taken enough English courses and assimilated mathematics and science concepts (which should not be a problem since students learn better in the language used at home). As a result, our students will identify math and science as part of our culture.

Some will probably resist this proposal, citing the lack of teaching materials and the unnecessary cost of producing new books and teaching aids. But these difficulties are temporary and once overcome, the textbooks will even enrich the educational system. The benefit is long term; students properly trained in basic mathematics and sciences are excellent starting materials for our technical and tertiary institutions.

Another important policy issue is changing the degree requirement to teach high school science and mathematics from BSE to BS. The BSE program is short on content and heavy on traditional pedagogy. Given the pervading situation in the country where the least intelligent in the family is encouraged to take education, our high school students tend to get their science and mathematics education from teachers who are most likely not qualified to teach these subjects.

This policy will receive stiff opposition from the many education schools in the country for they will not be able to handle the BS programs. They will lose students to the sciences and the better schools in the country. Unfortunately, these schools are in no position to immediately absorb the increased enrollment. But we cannot afford not to undertake this reform because the present system is precisely the cause of the poor performance of our students in science and mathematics. Besides, in many countries in the world today, a first degree in science and mathematics is the minimum requirement to teach in high school. Thus the reform has to be implemented but following a well thought out plan.

At the tertiary level, we need to institute an accreditation system to ensure the quality of our universities. There are too many universities and most are not able to offer quality undergraduate degree programs in math, engineering and the sciences. If we let this situation continue, not only are we shortchanging college students and their parents but perpetuating a system that produces degree holders who cannot practice their profession. Invariably, then, they end up doing something else: teachers who work as domestic helpers abroad, engineering graduates who do construction work, and so on.

Stiff opposition to this reform is also expected, particularly from SUCs and private schools. But CHED has to start implementing this reform for we have dilly-dallied enough on this problem. Accreditation is practiced worldwide and it is the counterpart of benchmarking in business.

The policies on hiring, promotion and tenure requirement of faculty members are better left to the universities. However, the government, through CHED, should emphasize to the universities that they should upgrade their policies every five years or so. This way, there will be a clear improvement in the faculty profile of tertiary institutions.

Research and development

The policy on R&D should not only delineate the responsibilities and areas of each sector but also promote an R&D agenda that will make us competitive in the 21st century. If clearly understood, then the development of the advanced technologies can be assigned primarily to the public sector and academe, while the private sector takes care of its own technological requirement. This policy shift has important consequences for DOST, the centers of excellence and the tertiary school system.

The compensation scheme for research work should be rationalized. Despite numerous complaints by the science sector (coursed through the DOST), the Commission on Audit still insists on a monthly research honoraria of P3,000. This policy is decimating the ranks of researchers in the centers of excellence. What good would well-equipped laboratories be without senior people? A simple policy statement allowing research honoraria to go as high as the basic pay depending on the productivity of the researcher as measured by publications and other creative work will tremendously improve the situation in the centers of excellence.

During the initial period of this long-term program, from the first up to the middle of the second mid-term plan, the government should provide incentives for reverse engineering and technology development. The reason is to induce the private sector to do R&D and also because the local firms will still need support for these activities. The incentives should be determined by the BOI.

But in the long term, the private sector should take care of its own technological requirements. At most the government should only provide the common facilities (engineering and technical databases, calibration and standards laboratory and maybe even an analytical services laboratory). But the funding of their R&D should be the responsibility of the firm and or the industry group.

To facilitate the transfer of advanced technologies developed in the centers of excellence and public R&D institutions, the government should issue a policy statement that will allow the easy transfer of results from these institutions to the private sector, including SMEs in S&T Parks. This policy will help upgrade the technologies of the private sector from the present low technology to the advanced technologies in less than two mid-term planning periods.

The private sector should also refrain from long-term technology licensing agreements and technology purchases in areas where the country has the capability. This would enable the establishment of SMEs (even in high tech fields) that offer engineering and technical services to large firms. Though difficult at the start because of the inexperience of local support industries and the colonial mentality of the general population (people go for foreign brand names), the current practice has to be curbed, if not stopped outright, if we are to move away from technological dependence.

What is the role of the public sector in this micro-practice reform of firms and industries? The BOI, through the Industry Development Council, can influence local firms and industries to adopt the reform by tying it to the provision of incentives (from the first to the middle of the second mid-term plan) and of support facilities (in the long term).

The BOT law should be revised to include a technology transfer provision, as this is the important first step in a developing economy's drive for technological self-reliance. The country should not be afraid to impose technology transfer because this is normally done by less developed countries in dealing with advanced economies. Besides, there is a big market out there of technology suppliers to choose from.

The private sector should be encouraged to practice "mirroring" in their joint ventures with foreign companies. Again, this is a micro-practice reform that should be suggested by the government to the private sector through the Industry Development Council. To entice compliance, the incentives cited earlier should also be tied to this reform.

S&T services

We need to undertake a major policy change with respect to DOST R&D Institutes that cater to the needs of the private sector (examples are ITDI and MIRDC). This change entails the privatization of these institutes so they can be more responsive to the needs of the industries they serve and at the same time make these industries responsible for their own technological requirements. However, privatization should not be done abruptly or irrationally because it will not accomplish the intended goal and will demoralize personnel. The details of these should be carefully and jointly discussed by the agencies and the industries concerned.

Government should convince international funding bodies like the World Bank, Asian Development Bank and OECD agencies to hire local consulting firms for feasibility studies of local projects. This will save the government money (local consulting firms do not cost as much as international firms) and will develop the expertise of local firms (even today, some local consulting firms do a much better job than international consultants) so that they can compete in international market.

Since the environment should be given serious attention, the front line agency in dealing with environment issues, the Environment Management Bureau, should be upgraded. The EMB, specially its regional offices, should be staffed by people trained in the sciences and engineering so they can measure pollution and monitor compliance with standards correctly and authoritatively.

5. Conclusion

What must we do to get ourselves out of the underdevelopment rut? The solution is obvious: we must break the vicious circle of economic underdevelopment and the dismal state of S&T. The solution is far from easy, given the cultural factors that hinder the development of science and technology in the country. Culture cannot be changed overnight. Besides we cannot change culture first and then develop science and technology. Cultural change and S&T development are a bootstrap process. To undertake cultural change, we must consistently implement programs in education, R&D, S&T promotion, rational planning and budgeting, etc.

To illustrate the difficulty, let us look at the problem of educational reforms. The long-term solution to improve the quality of science and mathematics education at the secondary level is to change the hiring policy for high school teachers, i.e., require BS rather than BSE. But the chance of this solution being implemented is rather small once the many educational institutions that offer the BSE programs realize they will lose enrollment. (I was informed by a former education Dean that we produce about 35,000 education graduates yearly.) Schools will likely run to Congress to block this policy reform. For this reform to see the light of day, the DECS Secretary must have a strong will and enjoy the support of the President.

One way by which teacher training institutions can effectively block this reform is to offer BS programs even if they do not have the faculty (MS and Ph.D. graduates in the sciences and not in education). Although an accreditation system is now in place, the generally low level of educational attainment of faculty members, especially outside Metro Manila, will most likely result in many unqualified schools gaining accreditation to offer BS programs. And this will be justified and accepted because we have to "make do" with what we have rather than simply accept the reform and implement it properly.

But all is not lost. There are two good experiences we can draw inspiration from as we implement the programs in the advanced technology areas. The first is the lesson learned in geothermal energy, one of the few scientific fields where the country is considered to be the leader in the world. When the author asked Dr. Alcaraz, the father of geothermal energy in the country, what the secret is of his success, his answer was very simple: diligent work, nothing less.

The second is the excellent performance of a Filipino venture capitalist in Silicon Valley, Mr. Diosdado Banatao. Mr. Banatao studied engineering at the Mapua Institute of Technology and semiconductor device physics at Stanford University. Now famous for developing the chip set and the graphics accelerator card, Dado Banatao has shown we can compete globally in the advanced technology areas.

Surely there are more Dr. Alcarazes and Dado Banataos in the country. In establishing a scientific and technological culture, we can start with a few scientists and technologists who have the dedication and tenacity to carry out programs and serve as inspiration to the youth. For the youth to remain inspired, we must consistently implement well-conceived plans and programs. If we do this consistently during the next 20 years, there is no reason why we cannot be the best in the world in the advanced technology areas.

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