Creating an Indonesian Science Fund

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Creating an Indonesian Science Fund is a collaboration between Indonesian Academy of Sciences and the World Bank, and was funded by AusAID.

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Contents

Executive Summary ... 2
The State of Science and Engineering in Indonesia ... 2
Where Does an Indonesian Science Fund Fit into This Picture? ... 4
Recommendations ... 6

Rationale for Establishing an Indonesian Science Fund ... 12
Promoting Excellence in Science and Engineering ... 12
Filling the Need for More Productive Science and Engineering Research and Entrepreneurship ... 13
Improving the Present State of Science and Engineering in Indonesia ... 18
- Gross Expenditures on R&D ... 18
- R&D Productivity ... 24
- Science Education ... 29

Raising the Low Number of Productive Scientists and Engineers ... 31
Satisfying the Need for an Appropriate Research Funding Mechanism ... 33

Objectives of an Indonesian Science Fund ... 36
Enable More Productive Fundamental, Applied, and Priority Research ... 36
Increase the Pool of Trained Research Scientists and Engineers ... 38
Foster Entrepreneurship and Innovation ... 39

Funding Instruments, Operating Principles, and Organizational Structure ... 40
Funding Instruments ... 40
Operating Principles ... 44
- Proposal Review ... 45
- Allocation of Grant Funds ... 48
- Staffing ... 49

Financial Accountability ... 49
Organizational Structure ... 51
Outreach and Evaluation ... 53

Institutional Framework ... 54
Recommendations ... 57
Appendix A Editorial in Science by Bruce Alberts ... 62
Appendix B Indonesian Science Fund: Estimated Costs ... 63
References ... 67
About the authors ... 68

Executive Summary

There is near unanimity among scientists in Indonesia that the country is not producing science or innovation at the rate it should. Primary evidence is the low number of publications and patents. Scientists believe the cause lies in the difficulties encountered in securing support for research projects and the inflexible budgeting and reporting systems in place. Less frequently mentioned are the heavy teaching loads of university researchers and the higher salaries offered for non-science careers in the LPNKs (non-ministerial governmental research institutes), both of which drive scientists away from research. The comparative data published by international sources confirm that Indonesian researchers are less productive than those in most comparable countries per dollar of research funds invested, and that Indonesia does not fall within the group of countries of its size and resources in the measures of national productivity for science and technology.

Indonesia does not have the financial infrastructure in place to support cutting-edge science and technology. Nor does it have an infrastructure in place to allocate and disburse funds to researchers, provide research facilities, or maintain a state budgeting system that would allow the flexibility needed for scientific research. Beyond these issues lies the larger one of a low national investment in research and development. Indonesia's gross R&D investment is less than 0.1 percent of GDP, which is almost too low to appear on the published charts.

These problems can be addressed together, as a system, by creating an autonomous Indonesian Science Fund that, on a competitive basis, would directly supply scientists and engineers with funds for world-class research. It would also require, as a condition of awards, the institutional support researchers need for increased productivity, while compensating institutions for costs incurred.

The State of Science and Engineering in Indonesia

Research and development activities are conducted in many institutions in Indonesia. The government provides over 80 percent of the research and development budget. The greatest number of scientists and engineers work in government scientific institutions, and they also receive the largest fraction of the country's R&D budget. But most of the PhD-level trained researchers work in the public universities. Aside from Vietnam, a communist regime, in Indonesia, of all the countries in the region, the private sector contributes the least to research and the university contribution is miniscule.

The low ranking of Indonesia in science and engineering is commensurate with the low national investment in R&D. By population, Indonesia, with its over 230 million people, is the fourth-largest country in the world. Illiteracy rates are very low, and the country has several good universities and research institutes. But for the years 1996–2010, Indonesia is in 64th place in the world in numbers of papers published in peer-reviewed journals. Moreover, about 74 percent of Indonesian scientific projects are international collaborations, so that the credit is shared with other countries.

The situation for patents is similar to that for publications. Although patents are more closely related to productivity in industry, many companies in diverse sectors do not apply for patents (or publish papers) for business reasons. Nevertheless, the low private sector expenditures on research and development probably are an important factor in the low number of patents granted to Indonesians.

A country with a scientific community that publishes widely in many different fields and produces patent-worthy innovation is more likely to produce innovations that can be taken to the marketplace. Perhaps more important, it attracts investment and joint ventures with technological companies that are seeking a technically trained workforce, as well as a market for their products. The size of the market depends on population, but also on its spending capacity, which feeds back into the number of foreign companies attracted and willing to pay good wages. In this complex relationship, the more capable the local science and engineering community, the more likely it is that advanced industries will be hiring local technical staff, and the more likely it is that these hires will produce innovations that lead to more new companies. In this second generation, more innovations will be the creations of local entrepreneurs.

Where Does an Indonesian Science Fund Fit into This Picture?

A national Fund that awards grants for scientific and engineering research on a competitive basis has been found by many countries to be the most effective way to encourage the best world-class science and engineering. Selection and renewal of grants based on results such as publications or patents impart the value of productivity in science. Because articles are themselves competitively selected for publication by the best international journals, researchers must be well connected worldwide if their research efforts are to be cutting edge. Countries foster innovation by seeking and supporting new ideas. They encourage researchers to submit their best ideas in investigator-initiated research proposals, in addition to the more prescriptive, results-oriented projects required by mission-driven agencies. Ultimately, successful new ideas will lead to new companies and products if training, support, and facilities are made available to entrepreneurs whose ideas go beyond publication.

There is little linkage in Indonesia between its scientific institutions and universities and the private sector, including the small and medium-size science-based enterprises that are the centers of innovation in most countries. According to the data, few scientists are working in the private sector, and the investment in technical innovation is small. The small size of most firms, the lack of clarity on what constitutes research, and the limited linkage between public research institutions and private firms are commonly mentioned as constraints to technology adoption. Most of the non-extractive industries are based on imported products with little added value. Additional policy incentives are needed to encourage higher added value and innovation.

At the same time, the current public financing mechanism provides very little incentive for public R&D institutions to collaborate with the private sector. For example, the current fiscal law calls for all government entities to be fully financed by the national budget, and the budget appropriation is supposed to be adequate to conduct all research activities. This means that any funds awarded to public agencies or universities by private or external sources must be submitted to the Ministry of Finance, where it becomes nontax revenue that can be reclaimed only through budget lines in the annual national budget process. Scientists who wish to participate in a donor-funded project must collaborate with foreign colleagues and ask their collaborators to accept the grant and reimburse the expenses of the Indonesian partner. This is hardly a basis for cooperation among equals.

The relatively low rate of publication in the sciences is not a direct reflection of the number of scientists and engineers in Indonesia, nor solely of the level of investment in science and technology. Some smaller countries with far fewer scientists and engineers are leading Indonesia in scientific output per dollar of investment. The problem is more systemic and has to do with allocation of resources, including human resources, and the research environment, which may not be conducive to the freedom and autonomy necessary for innovation. The career track for scientists is rigid, and it limits opportunity for researchers. It also limits risk, leaving scientists free to carry out little productive research without penalty. Advancement in scientific careers in universities as well as in the governmental LPNK research agencies should be based on quality of output and contribution to knowledge or technology. A competitive funding resource such as an Indonesian Science Fund based on excellence, originality, and capability would provide incentives and rewards that furthered these goals.

There are many successful models of programs to train and support entrepreneurs and promote entrepreneurship. Some of the most successful are university-based, where they assist students and faculty to develop and market the results of their research, sometimes to the great benefit of the universities themselves. These models involve incubators where new businesses can operate and share facilities and consult with experienced businessmen and women, and where they can gain access to venture capital and other resources. Grants can be given to universities to establish incubators to serve the academic community and others.

The different objectives of the Indonesian Science Fund require different funding instruments. Each will be directed toward achieving results related to the specific objective, but any grant or award to an institution can include more than one of these instruments:

1. *Principal investigator research grants* will serve as the principal funding instrument for researchers. They will be awarded to the host institution for the exclusive use of the principal investigator and may include equipment acquisition, training, publication costs, and overhead.

2. *Travel grants* would be awarded to individual investigators for participation in a conference, a visit to another laboratory for a short period, either abroad or within Indonesia, or a visit of a foreign scientist to a laboratory in Indonesia, in order to stay abreast of cutting-edge developments.

3. *Student fellowships* would assist students who are working toward advanced degrees in a science or engineering field in an Indonesian institution.

4. *Industrial cooperative fellowships* would enable students to work within a private company or LPNK on a project related to the students' interests.

5. *Cooperative research awards* would support joint research by industrial or LPNK scientists and university scientists.

6. *Entrepreneurial support grants* would be awarded to universities to develop programs to assist students, faculty, and others to market and commercialize original inventions, products, or other commercializable intellectual property.

7. *Grants for educational research* may complement principal investigator research grants on educational topics, and enable new methods, curricula, or syllabi to be tested in schools.

Recommendations

International evidence shows that most countries, led by the member countries of the Organisation for Economic Co-operation and Development (OECD) and European Union, are moving toward quasi-autonomous professional granting agencies, with independent merit review processes to support research grants and development projects in both the private and public sectors. There are basically three ways this could be done in Indonesia:

1. This task could be taken up by a government agency, possibly the Ministry of Research and Technology (RISTEK).
   Pro: Some of these institutions already have facilities and research staff who are familiar with granting procedures. They also have project accounting mechanisms in place. Start-up time could be reduced.
   Con: One of the major constraints to creating a new research and development program in Indonesia that affects all public institutions is the government's rigid line-item annual funding mechanism and lack of flexibility in the use of funds. The creation of a granting facility within a government agency would require major revisions of budgetary law and regulation. Furthermore, most government agencies have dedicated intramural research programs related to their missions. Competition for research funds could damage the effectiveness and the reputation of the competitive program.

2. The task could be assumed by a non-governmental organization.
   Pro: The problems associated with government agencies would not be a factor.
   Con: There are difficulties in allocating government funds to non-governmental organizations. The government would have no direct influence on the policies and programs of the Fund, and the Fund might not coordinate its work with national science and technology policy. This could generate friction with a future government to the detriment of the nation's science and engineering.

3. The task could be taken on by an independent, dedicated agency with partial government funding and the capacity to raise other funds from private and international sources.
   Pro: This agency could be housed under an existing independent government-funded institution, while remaining separate and autonomous. It could create an endowment to support future research investment. An autonomous Fund under the umbrella of an independent institution, with significant government participation, could avoid the pitfalls associated with government agencies while providing a voice for government in policy decisions.
   Con: The budget and scope of activities are likely to be much greater than that of the host institution, and may overwhelm its staff and overshadow its primary purpose.

RECOMMENDATION 1: An Indonesian Science Fund(ISF) should be established under the auspices of the Indonesian Academy of Sciences (AIPI).

AIPI is a non-governmental entity, but established by a Law of the Republic of Indonesia (Law No. 8/1990) that explicitly stipulates government financial support as well as the freedom to seek non-government funds. As such, it is exempt from the financial regulations that inhibit fundraising and multiyear planning. At present, AIPI has a small city office in central Jakarta, in addition to its facility in Serpong, but the ISF should be housed in its own building facility in Jakarta.

Initially, the ISF should accept four types of proposals from applicants:

1. Unsolicited research proposals from scientists, social scientists, and engineers. These may be for either basic or applied research.

2. Applied science proposals in response to requests for proposals (RFP) in one of the designated priority areas. One of the early RFPs should request proposals for facilities to support entrepreneurship. These may be based on one of the many successful models applied in other countries or one unique to Indonesia.

3. Proposals on science education. This is essentially an applied science program, but one that is continuing in an effort to develop new curricula, teaching techniques, and course materials to increase the number and quality of science students in primary and secondary grades.

4. Fellowships for graduate students applying for advanced science degrees in Indonesian universities. These will be high-prestige fellowships that will persuade some of the best students to remain in Indonesia for their graduate study.

The grants themselves could utilize one or more of the funding instruments described earlier. For example, a research proposal could include travel and student assistantships, as well as principal investigator research funds.

Staff should be recruited and trained as needed to manage the proposals and programs submitted. In addition to a core permanent staff, some of the program managers should be on loan from universities and LPNKs for two-year terms, after which they return to their own institutions. These managers will be responsible for proposing to the ISF director which applicants should receive grants, the highest responsibility in the Fund. The constant rotation will give scientists a feeling of participation and prevent the growth or perception of bias in any programs. ISF staff should prepare online materials for assistance and guidance in proposal preparation, submission of proposals, reviews, and response to review.

Appendix B contains a cost estimate per year for the Indonesian Science Fund. It is assumed that there will be 8 divisions, such asphysics, chemistry, biology, engineering, agriculture, medicine, energy and environment, and social science and education. The research budget proposed is 360 billion rupiah for 250 new three-year grants, per year, averaging 1.5 billion rupiah. For the cost of administration and review of proposals, the rate of 20 per cent, common to similar grantee agencies, is used. The total annual budget for research and administration is 414 billion rupiah, or U.S. $44 million. This budget figure will allow purchase of needed equipment for new grants, permit training of staff and students, and travel to initiate cooperation and exchange of information with other research groups, both in Indonesia and abroad. This number of grants is within the capability of a new organization and a relatively small number of candidate grantees, that is, PhD-level scientists who have active research programs and are not already fully supported by other organizations. For grants renewed in later years, with equipment already purchased, grants may become smaller, leaving more funds available to increase the numbers of grantees. The number of grantees working at any time within this budget figure could possibly exceed 1,000, but, eventually, for a country the size of Indonesia, the budget should be raised.

The present science and engineering system in Indonesia does not permit researchers to seek funds for research projects from international or domestic sources without putting at risk the funds already received from their organization. This arrangement often forces them to collaborate with foreign researchers in the following way: the foreign partner receives all funds and then subcontracts with the Indonesian partner for part of the work, placing the Indonesian partner in a subordinate position in the research team. This is not necessarily acceptable to all donors, and the Indonesian may lose an opportunity to participate.

One of the major constraints to creating a new research and development program in Indonesia that affects all public institutions is the government's rigid line-item annual funding mechanism. Current Indonesian fiscal law and regulation discourage multiyear research programs, although they allow year-by-year renewal. And they offer no flexibility in the use of funds. In some programs, acquisition of equipment is not permitted.

RECOMMENDATION 2: Remove the requirement that any funds collected from private or external sources for research purposes be submitted to the Ministry of Finance as nontax revenue and to be reclaimed through budget lines in the annual national budget process. Permit recipients of ISF grants to utilize the funds outside the annual budget process for purposes described in the grant, including multiyear projects.

At present, scientists and engineers in government agencies must choose early in their careers whether they wish to follow an administrative or research career path. Even those who have received specialized training in science or engineering will hesitate before choosing a path that has less lucrative salaries and positions,and brings their dedication to their families in conflict with their scientific interests. The terms of the research career should encourage the best researchers to select a career that fully uses their skills.

RECOMMENDATION 3: Eliminate the distinction between the research and administrative career paths, and make the salary and benefits the same for both.

The granting of research awards to an institution has economic consequences for that institution. Research requires the support of administrative staff for accounting services, purchase and maintenance of equipment, and care of laboratories. The demand for energy, water, and space increases. In some cases, the teaching staff may have to be supplemented.

It would be counterproductive for the ISF to force the institutions that receive grants to pay the costs that obviously are associated with the research project. Equally negative would be the effect of putting financial pressure on administrative staff, deans, or directors. Instead, the ISF should provide incentives for them to encourage their researchers to apply for grants.

RECOMMENDATION 4: Allow the ISF grantee institution, whether university or LPNK, to receive overhead payments to support the indirect costs of research without subtracting the amounts from existing revenues.

Rationale for Establishing an Indonesian Science Fund

Promoting Excellence in Science and Engineering

Today, countries have found that their status as a nation is determined to a large degree by the quality of their scientific enterprise. For reasons that seem to have little to do with economics, China is preparing to send scientists to the moon, while other countries are hoping to visit Mars. Meanwhile, many nations are participating actively in the international study of global climate change and the international effort to conserve biodiversity. The United States has declared that scientific cooperation will be the cornerstone of its relations with the Muslim-majority countries, a proposal that has been warmly received by those countries, including Indonesia. To many, excellence in science implies a culture that extends beyond the laboratory and is characterized by high standards of conduct, integrity, transparency, accountability, and reward for merit and performance. Furthermore, excellence in science requires a country to engage the entire world and be measured by international standards.

Of course, a nation that pursues excellence in science also receives concrete benefits. The most obvious are the economic ones. Indeed, as will be shown shortly, GDP is strongly correlated with the volume of scientific publications in peer-reviewed journals.

Scientists and engineers contribute to economic growth in many ways in today's technological societies: by working in industry, by attracting foreign direct investment, and by making discoveries and innovations that reverberate in the marketplace. But to produce and grow, the scientific estate must be nourished by the funds needed to support research. And to produce the best effect, the funds must be given to the best researchers in a manner that allows them to use them in the most effective fashion. A fair, equitable, transparent research funding system not only advances science and engineering, but also serves to attract the best researchers and students to scientific careers.

The general attributes of an excellent scientific community are integrity and dedication to pursuit of knowledge, the transparency that enables scientists to confirm each other's discoveries, and accountability and service to the nation. This service includes education, health care, national security, environmental protection, and technical advice to government. It also includes providing a window into the knowledge and technology generated in other parts of the world. The benefits to Indonesia of a globally engaged S&T enterprise are an enhanced status as a world leader, opportunities worldwide for cooperation in science and technology, and a chance to demonstrate to the world industrial community the benefits of R&D investment in the vibrant, globally connected science and technology environment of Indonesia.

In most countries that have an active technology sector, an agency, governmental or autonomous, is dedicated to supporting science and engineering research with a competitive, merit-based process and to maintaining the standards and goals of science and scientific research in the country. At present, Indonesia lacks such an agency. Support for science and engineering research is distributed among several ministries whose research facility serves their own missions and responsibilities rather than the other way around. In the effort to achieve the mandated goals of these ministries in a timely way, scientific excellence and the needs of scientists are not given the highest priority in the short term. When the responsible agency must cure a disease, launch a rocket, or build a reactor, it cannot spend the time or resources—nor should it—to experiment with the new ideas that might lead to greater advances and innovations in the future. This could be the role of an Indonesian Science Fund, dedicated to excellence in science, engineering, and science education.

Filling the Need for More Productive Science and Engineering Research and Entrepreneurship

Over the last several decades, the modern world economy has become strongly influenced by two major forces, globalization and innovation. Globalization has created value chains within and among companies in different countries that have generated new world markets in many areas. The term multinational corporation, which used to refer a small number of large and influential companies with branches, suppliers, and markets in several countries, now describes a majority of companies in many sectors, from services to manufacturing to energy and natural resources to retail sales, and includes research and development, pharmaceuticals and health care, and education. Except in a few basic industries such as housing construction and food, the phrase "Made in America" or "Made in Indonesia" rarely describes a product whose labor and materials come exclusively from one country, and usually not even a product that was designed or invented there. Even small and medium-size enterprises generally import components, parts, materials, and business services from abroad, and at least attempt to serve an international market.

Innovation, classically considered fundamental to economic growth, has now become the dominating competitive factor in the world market. Among high-technology companies, the impact of innovation is so great and the competition in the market so high that the relative ranking of companies fluctuates, sometimes with startling frequency. The rate of innovation in the present high-technology market, with its basis in new and fundamental science, has nearly obliterated the distinction between fundamental and applied research. Not even the researcher can know whether the outcome of a project on nanotechnology will be new fundamental knowledge about the behavior of small particles, a new adhesive material quickly developed, a new effective pharmaceutical developed over the long term, or none of the above—this time. Even astronomy, that most quintessentially pure science, has produced innovations in optics, nuclear chemistry, and even dermatology, where software designed to detect small changes over time of a complicated pattern of specks and blotches in the sky has been applied to detect potential skin cancers (see box 1). As explained through a separate series of 20 examples generated by the U.S. National Academy of Sciences, the most fundamental of all research—aimed simply at deciphering how the world works— often ends up producing the most dramatic and unexpected breakthroughs that benefit humanity (see http://www.beyonddiscovery.org).

BOX 1. TECHNOLOGICAL ADVANCES FROM FUNDAMENTAL RESEARCH

Here are a few examples of well-known and highly successful technologies that arose directly from unsolicited research projects. Source: NSF Sensational 60, 2010.

People wondered why the blood of fish in the Antarctic does not freeze in the subzero temperatures. Researchers in Texas discovered antifreeze glycoproteins in the blood, produced by the pancreas and stomach of the fish. The proteins are now used in ice cream, cosmetics, farmed fish, and frozen foods, and to preserve tissues for transplant.

In the early 1990s, the internet was new and there were only about 100 websites. A group of students at Stanford University realized that search engines would soon be necessary. An NSF award to Stanford in 1994 supported two groups of students, who took different approaches to web searches. One pair developed Yahoo!, and the other two students founded Google.

Nanotechnology uses microscopic techniques to rearrange molecules with different shapes and features to form new materials with new properties and functions, such as conductivity, optical properties, mechanical strength, and chemical reactivity. This has led to new discoveries in solar cells, medical diagnostic screening, groundwater purification, and super-strong materials.

Soil contamination with heavy metals or organic chemicals is a worldwide problem, and costs of removing affected soil are wildly expensive. Recently, biotechnologists and plant improvement specialists have developed cost-efficient methods of using plants to remove or neutralize toxic materials and heavy metals from soils. Some plant species accumulate large amounts of heavy metals, and the basic understanding of the process has led to the engineering of synergistic bacteria that accelerate the process so that remediation can be carried out preventively and economically.

Astronomers and cancer researchers both have to deal with the problem of scanning blurred or cluttered photographs for signs of changes over time. Astronomers and cancer researchers have collaborated in a project to adapt astronomical computer software, developed to scan regions of the sky containing millions of stars, to scan mammograms. The software removes the unchanging background in the image and detects growing micro calcifications, a possible sign of cancer, speeding up the diagnostic reading and analysis in the process.

However, although innovation has driven changes in the fortunes of countries and companies, its impact has often been greatest in countries that were not the origin of the innovations. From the industrialized countries, there are complaints when their innovations are developed and marketed in developing countries, and those complaints are especially loud from labor organizations because costs of manufacture are lower in the developing countries. But even if all the scientists and engineers in the world were equally well prepared and well supported—but most of them were still working in the United States, Europe, and China, as they are today—the distribution of innovations would not be much different than it is. Most innovations arise where the innovators work. Today, even the occasional valuable invention that would emerge from a lower-middle-income country such as Indonesia would be likely to end up being commercialized and becoming an innovation in another country. The inventor in Indonesia of a valuable new process or product who wished to form a local company to capitalize on it would need to immediately hire a large number of capable scientists and engineers. If he or she could not find them locally, the invention would end up being sold or moved to another country with a large supply of scientists and engineers and economic policies and culture that favor new start-ups. Countries that wish to exploit new technologies regardless of their origin must prepare themselves in different ways from those that simply rely on their own innovative capacity. Many innovative companies in North America and Europe are moving manufacturing plants to developing countries where they can hire the scientists and engineers they need at lower cost and in greater numbers. These scientists and engineers learn the technology and the business and can become the next generation of innovators. But first they must be educated and trained.

Innovation is often confused with *entrepreneurship*, and the two words are often used interchangeably. Technical innovation is a new way of making or doing things, which could be an invention, a new process, or a new use for an existing technology *that finds success in the marketplace*. It is usually carried out by teams of scientists and engineers. The term *innovation* is normally applied only after an invention has achieved commercial success, and *innovator* is really an honorific title, not a profession. Today's best-known innovations, such as Apple Computer's line of products and the advances of the biotechnology industry, were developed by dedicated teams of scientists, some of them in direct competition with each other. *Entrepreneurship* is the act of creating enterprises for doing business, whether based on innovation, location, skills, or timing, and it is frequently associated with enterprising individuals such as Steve Jobs, late CEO of Apple Computer Co. (Isaacson 2011) and Herb Boyer, who started Genentech.[1] Technological innovations without entrepreneurship will not lead to new products or companies. Technical entrepreneurs without skilled scientists and engineers to develop their projects will not succeed in their own countries and so will take their talent and ideas elsewhere.

Both innovators and entrepreneurs require specialized skills and rare innate ability. There is, however, one important difference: entrepreneurs can be trained. And an entrepreneur, working together with scientists, can duplicate the function of an innovator.[2]

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1 http://www.nndb.com/people/316/000127932/

2 This thesis is illustrated very clearly in the career of the Steve Jobs, cofounder of Apple Inc., a computer company. Jobs was a brilliant entrepreneur. He knew what would sell in the market, and he knew how to generate markets for new devices. But he was not an inventor himself, and he could not program or build computers. In fact, he barely had an undergraduate education. But working with his engineers, he was able to produce the products that made Apple one of the most successful and innovative companies in history.

A country that is prepared to compete in the arena of science, technology, and innovation and is not presently among the leaders in all three of these fields must adopt a different strategy—one that has been exploited by several of the rising "tigers" of international competition such as the Republic of Korea, Brazil, India, and China. That strategy involves having a large and flexible labor pool, a broad network of suppliers, access to venture or start-up capital, and excellent educational institutions and research laboratories that areproducing a large cohort of motivated scientists and engineers. It must prepare and encourage skilled entrepreneurs and provide a business environment that promotes success, while encouraging risk-taking and tolerating failure. And it must implement a policy of technology transfer that includes joint ventures with foreign technology companies, return of successful and skilled emigrants, promotion on merit, recruitment of expatriates for special leadership assignments, and encouragement of international training, communication links, and scientific collaboration for scientists and engineers.

It is well known in industry that most innovations occur on the factory floor, generated by the on-site engineers and workers who understand the products and processes best. The advantage belongs to those who are already engaged. For example, a Korean company is now the world's second-largest producer of semiconductors, although Koreans did not invent the semiconductor or the microchip. Korea, however, produced a generation of widely published scientists and engineers, and it had a generous attitude toward foreign investment. Many of the scientists worked at specialized institutions such as KAIST that had strong links with foreign institutions, and some of these institutions were led by famous expatriate leaders for short periods. This attractive environment induced Intel, the world's leader in microchips, to establish manufacturing facilities in Korea, staffed by Koreans. The Korean workers and engineers soon learned and improved the manufacturing process, and eventually Korean companies were also able to offer excellent products at good prices to foreign companies.

Improving the Present State of Science and Engineering in Indonesia

Gross Expenditures on R&D

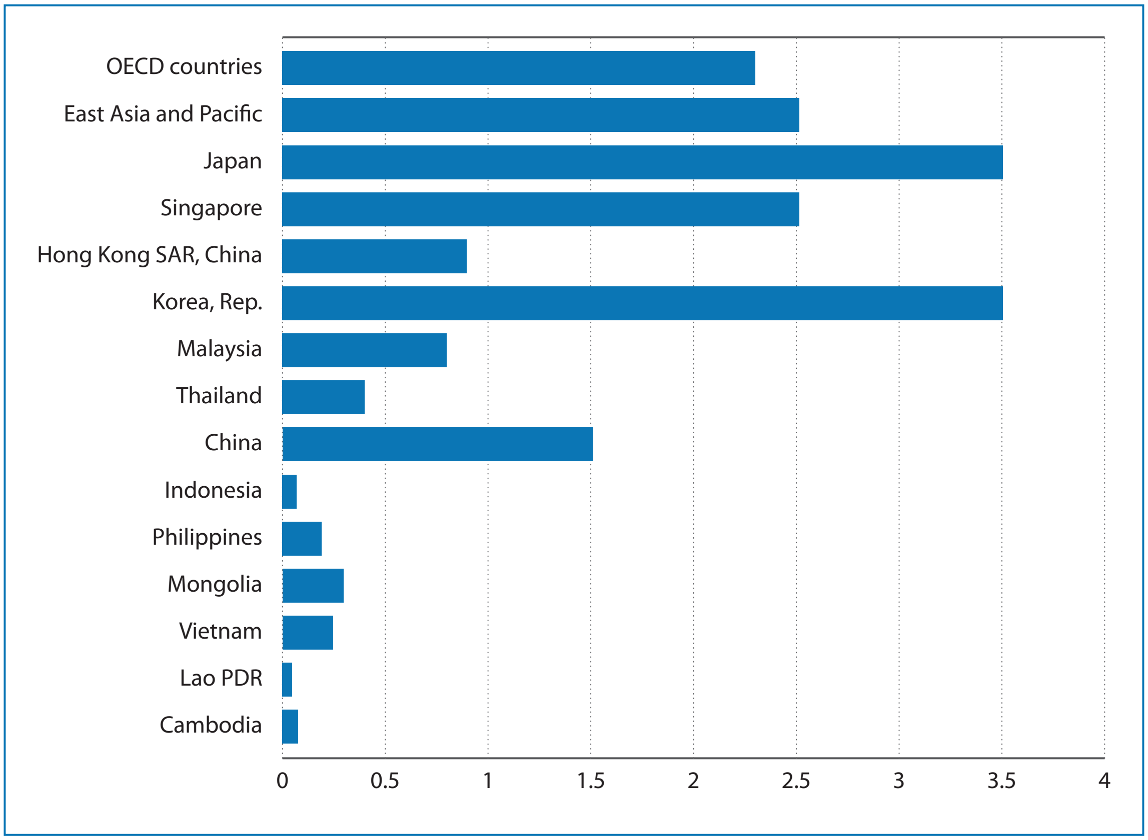
Research and development activities are conducted in many institutions in Indonesia. The greatest number of scientists and engineers work in government institutions. These include the non-ministerial research institutes (LPNKs), which are the Indonesian Institute of Science (LIPI), Agency for the Assessment and Application of Technology (BPPT), Nuclear Research Agency (BATAN), Space Agency (LAPAN), and Meteorology and Climatology Agency (BMKG), as well as the R&D agencies of the line ministries, including the Ministry of Health and Ministry of Agriculture. Most of the PhD-level researchers work in the public universities. Some non-governmental institutions also conduct R&D activities, and some R&D is carried out in private industry.

The fiscal laws and regulations governing the budgeting mechanism prescribe that R&D allocations for the line ministries be included in the budgets of the ministries. The Ministry of Health and Ministry for Education and Culture have their own annual R&D budgets, which are allocated to health research institutes and to the universities, respectively. These amounts are considered sufficient for the R&D related to the missions of those agencies.

Data published by the UNESCO Institute of Statistics for 2011reveal that in Indonesia about 80 percent of R&D funding comes from the government and about 14 percent from the private sector.

By contrast, Malaysia, China, Japan, Korea, and Singapore receive over 60 percent of their research investment from the private sector. Other countries are under 50 percent, but most are higher than Indonesia. With total R&D expenditures of $44 billion a year, Korea spends far more than Indonesia ($1 billion a year) in every sector.

FIGURE 1. GROSS EXPENDITURE ON R&D AS A PERCENTAGE OF GDP, EAST ASIA AND OECD



Source: World Development Indicators database (latest year, 2002–07).

With investment in R&D of less than 0.1 percent of GDP, Indonesia ranks far lower than any of the countries listed in figure 1, which includes most of those with which it competes or hopes to compete. Even were a new funding agency with a new approach not under consideration, an increase in R&D expenditures would be needed to strengthen Indonesia's competitive position in innovation and the global marketplace.

According to table 1, in 2001, 81 percent of the R&D expenditure in Indonesia was provided by the government. Under the current fiscal regulation, the R&D activities financed by government are severely constrained, as discussed shortly, and projects are not always selected according to merit or track record. As noted, among countries in the region, the private sector contributes the least to researchin Indonesia and Vietnam, and the university contribution is miniscule. However, the total in Indonesia is also small, and so a new source of research funds may make a significant contribution.

TABLE 1. SOURCE OF R&D EXPENDITURES IN SOUTHEAST ASIA (PERCENT)

Economy	Business enterprises	Government	Higher Education	Private nonprofit
Vietnam	14.5	66.4	17.9	1.1
Philippines	68.0	19.1	11.1	1.8
Indonesia	14.3	81.1	4.6	0.0
China	71.1	19.7	9.2	0.0
Thailand	43.9	22.5	31.0	2.6
Malaysia	71.5	10.4	18.1	0.0
Korea, Rep.	77.3	11.6	10.0	1.2
Hong Kong SAR, China	48.3	2.2	49.5	0.0
Singapore	65.7	10.4	23.9	0.0
Japan	77.2	8.3	12.7	1.9

Source: UIS Data Centre.

Note: Data years: Hong Kong SAR, China, and Malaysia, 2004; Vietnam, 2002; Indonesia.2001; other countries, 2005–08.

TABLE 2. NUMBERS OF RESEARCHERS PER MILLION POPULATION, SELECTED COUNTRIES

Country	Researchers per million inhabitants latest available year
Finland	7,707
Iceland	7,315
Singapore	6,088
Denmark	5,670
Japan	5,573
Norway	5,468
Sweden	5,239
Luxembourg	4,748
USA	4,663
Republic of Korea	4,627
Malaysia	372
Mexico	353
Uruguay	346
Thailand	311
Monaco	308
Sudan	290
Brunei Darussalam	281
Senegal	276
Guinea	253
Indonesia	205

Source: ChartsBin, http://cdn3.chartsbin.com.

Table 2 compares the numbers of researchers by country per million of population. Indonesia ranks number 77 in the world. The low ranking of Indonesia is commensurate with the low investment, and can be expected to rise when additional resources create incentives for students and expatriates.

We should note that tables such as this tend to understate the progress of countries like Indonesia. The Western nations at the top of the chart have aging populations dominated by mature, working adults. In developing countries, often more than a third of the population is under working age. Children do not do research, and the effectiveness of the scientific community is not measured by its percentage of the population. That measure entails a race with population growth that will not be won in the short term. Comparisons cited in the remainder of this report rely on total numbers of researchers and their outputs, or numbers normalized to total GDP.

Table 3 shows the low number of full-time researchers employed in the private sector in Indonesia compared with other countries. The discrepancy in the total number of researchers is unexplained by UNESCO, but it might be a product of the combination of data from two separate years.

TABLE 3. NUMBER OF RESEARCHERS IN SELECTED COUNTRIES BY SECTOR OF EMPLOYMENT AND FULL TIME EQUIVALENT(FTE),LATEST YEAR AVAILABLE

Country (year)	Total	Business	Government	Higher education
Brazil (2008)	133,000	50,000	6,900	76,000
China (2008)	1,592,000	1,092,000	240,000	261,000
India (2005)	155,000	57,000	75,000	22,000
Malaysia (2006,2008)	9,700	3,500	1,600	9,500
Singapore(2008)	28,000	17,000	1,700	13,000
Thailand (2007)	21,000	5,000	3,100	13,000
Turkey (2009)	58,000	21,000	5,700	31,000
Indonesia, FTE (2009)	21,000	250 (2001)	6,300(2006)	7,500
Indonesia, head count (2009)	41,000	2,000	11,000	22,000

Source: UNESCO Institute for Statistics, 2009.

According to table 4, exactly twice as many scientists and engineers are employed in Indonesia's universities as in the government sector, and 80 percent of the PhDs are in the universities.[3] The number of newly graduated PhDs in 2009 in Indonesia was about 0.1 percent of the reference age cohort as computed by OECD, giving Indonesia a ranking of number 36 in the world (OECD 2011).

[3] The exact factor of two between five-figure datain these columns casts doubt on the accuracy of these figures, and the inclusion of bachelor's and non degree workers as researchers casts doubt on their significance. Nevertheless, the figure of 40,000 total Indonesian researchers has been adopted by many of the international databases, including the UNESCO database, which is the source of table 3, and is the basis for the comparisons in other tables as well. University head counts are particularly misleading because many professors teach at more than one university, and those who do tend to contribute less to research than full-time employees.

TABLE 4. HEADCOUNT OF R&D PERSONNEL BY DEGREE AND PLACE OF EMPLOYMENT: INDONESIA, 2009

Type of R&D Personnel	Manufacturing Industry Sector	Government Sector	Higher Education Sector*	Total
Researchers	7,588	11,114	22,228	40,930
Ph.D	19	1,353	5,458	6,830
Master	-	4,025	16,770	20,795
Bachelor	4,374	5,736	-	10,110
Non-degree	3,195	-	-	3,195
Technicians	2,135	7,572	1,484	11,191
Other supporting staff	1,144	8,575	1,334	11,053
Total	10,867	27,261	25,046	63,174

**public universities*

Source: LIPI, 2009. R&D survey in university sector (2009), industry sector (2010) and Government sector (2006)

TABLE 5. GROSS R&D EXPENDITURE BY SECTOR AS PERCENTAGE OF GDP

Sector	Expenditure (RpX10^9)	Percentage of GDP
Higher education (a)	1,821	.032%
Manufacturing Industry (b)	880	.017%
Government (c)	2,019	.036%
Total	4,720	.084%
Non-degree	3,195	-
Technicians	2,135	7,572
Other supporting staff	1,144	8,575
Total	10,867	27,261

Notes: a) Based on R&D Survey in universitysector, 2009
b) Based on R&D Survey in industry sector, 2010
c)Based on R&D Survey in Government sector, 2006
Indonesian GDP=Rp5613 X10^{12} (trillion)
Source: LIPI 2009.

In Indonesia, only 38 percent of the total support for R&D goes to the universities; 43 percent goes to the government agencies (table 5). In other words, research support is presently not concentrated in those institutions in which most scientists, students, and nearly all the PhD researchers are employed. Because LPNK researchers can work full time on research, whereas university researchers commonly teach four classes, this allocation emphasizes the inefficiency of the distribution, which is distinctly unfavorable to those trained to do research. The next section describes how that low investment and inefficient allocation are reflected in the principal indicators of scientific productivity.

R&D Productivity

Excellence in science and engineering, as in most academic disciplines, is commonly measured by examining its direct product: articles published in peer-reviewed scientific journals. To judge architects, one must look at buildings; to judge lawyers, one counts cases won and lost. In either case, conclusions must take into account the opinions of other architects or lawyers since not all buildings or cases are alike. Scientists and engineers produce journal articles and patents that have already been judged by their international peers in the process of publication in established journals, and on a national basis articles and patents can be simply counted and compared with those of other countries. It may be hard to judge which countries lead in architecture or law, but there is no debate about which countries lead in science. The numbers of published scientific papers, and their impact measured in citations in other scientific papers, are the criteria for scientific excellence, for individual scientists, for institutions, and for nations. For individuals, there are also the public prizes awarded, of which the best known is the Nobel Prize, but prizes are less informative in comparing nations because they are highly skewed toward the top countries on the publications list.

It is important to understand the importance of scientific publications. It is not that these publications are the product most treasured by companies or countries. However, publication serves as a useful index of research activity and training. A high level of publications from a particular country indicates that many people in that country know how to do research. Some of them may have published only one paper—a thesis—before joining an electronics company. Others may have spent their lives publishing papers and teaching students to do research.

Innovators do not necessarily publish papers. But it was the opportunity to learn to do research that attracted the founders of Microsoft and Facebook to Harvard (though they did not graduate) and the founders of Google and Apple to Stanford, which suggests that if institutions like those were not available, they might have taken their skills out of the country. The number of published papers is the self-selected measure of the academic community and a requirement for advancement in the scientific world.

Table 6 is a ranked list of selected countries according to numbers of publications and citations. Citable documents are journal articles, review articles, and conference reports.

Indonesia is the fourth-largest country in the world by population, with over 230 million people. Illiteracy is very low, and the country is home to several good universities and research institutes. But Indonesia is in 64th place in the world in numbers of publications in peer-reviewed journals during the years 1996–2010. In the year 2010 alone, its rank was 61st. Moreover, about 74 percent of Indonesian scientific projects are international collaborations, so that the credit is shared with other countries (OECD, Science, Technology, and Industry Scoreboard 2011, 47).[4]

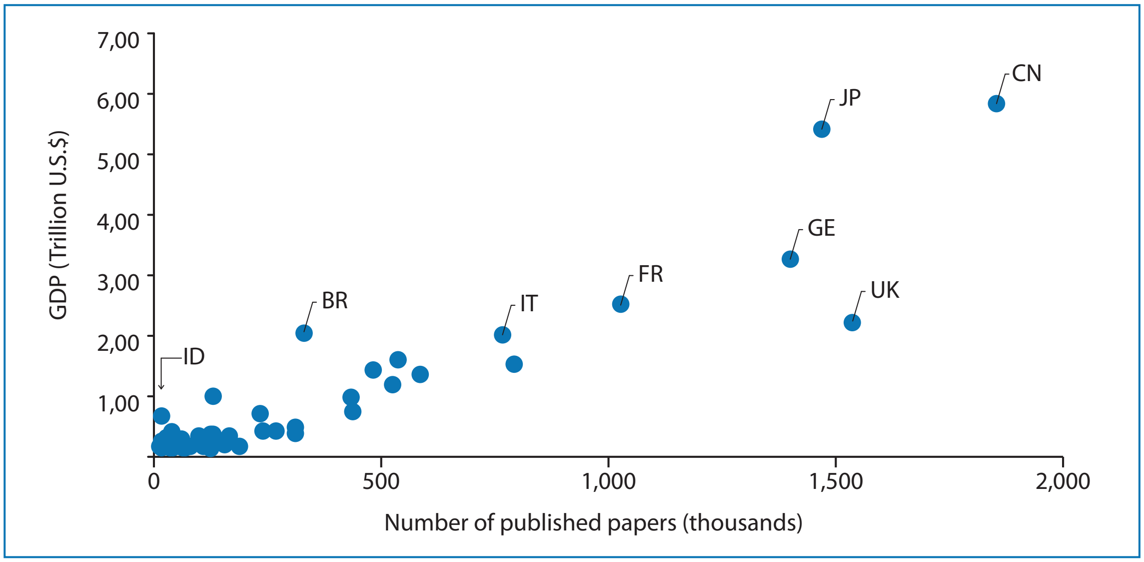
[4] On April 28, 2012, KOMPAS, the largest newspaper in Indonesia, published an interview with Wong WoeiFuh, managing director of Asia Pacific Intellectual Property and Science at Thomson Reuters.
Wong said that research carried out by his company ranked Indonesia third in Southeast Asia in quality of research, after Singapore and the Philippines, although quantity is low. Areas of greatest strength were found to be botany, zoology, medicine, environment, geology, and agriculture.

TABLE 6. COUNTRY RANK OF SCIENTIFIC PUBLICATIONS, 1996–2010

Rank	Country	No. of documents	Citable documents	Citations
1	United States	5,322,590	4,972,679	100,496,612
2	China	1,848,727	1,833,463	7,396,935
3	United Kingdom	1,533,434	1,392,982	24,535,306
4	Japan	1,464,273	1,429,881	16,452,234
10	India	533,006	507,792	3,211,864
11	Australia	520,045	485,249	7,083,995
14	Korea Rep.	430,438	422,745	3,344,131
15	Brazil	328,361	318,294	2,409,214
17	Taiwan	308,498	301,775	2,391,691
21	Turkey	231,178	219,280	1,380,599
31	Iran	120,350	117,469	499,322
32	Singapore	109,346	105,665	1,092,233
33	New Zealand	101,286	95,295	1,309,197
42	Thailand	59,332	57,509	442,250
43	Malaysia	55,211	53,979	218,280
62	Estonia	14,366	14,106	150,084
63	Bangladesh	13,657	13,304	80,533
64	Indonesia	13,047	12,776	105,759
65	Kenya	12,982	12,350	153,702
67	Kuwait	10,981	10,723	69,937
68	Vietnam	10,904	10,676	89,244
70	Philippines	9,717	9,440	103,428

Source: SJR — SCImago Journal & Country.

FIGURE 2. GDP (2010) VERSUS NUMBER OF PAPERS PUBLISHED: SELECTED COUNTRIES, 1996–2010. U.S. NOT INCLUDED



Sources: Table 6 and World Bank(http://data.worldbank.org/country)

Figure 2 shows explicitly the relation between the scientific capacity of a country as measured in publications and GDP, the measure of wealth and industry, for the 50 countries with highest GDP, minus the United States, which would be off the chart. The relation is almost linear at the lower levels with little scatter. Over most of the range, the GDP of a country can be reliably predicted to within a factor of two by the number of scientific publications. Indeed, few other indicators are as reliable as a predictor of GDPas number of scientific publications. The OPEC countries and others that export natural resources, Indonesia (ID) among them, are clustered at the lower left. In time, the GDP of these countries might be expected to decline as the resources are exhausted, while the GDP of those more dependent on industry and technology may increase.

In 2007 the Indonesian government issued a long-term national development plan for the period 2005–25, together with a Master Plan (MP3EI) for implementation.[5] The vision of the plan was acceleration and expansion of Indonesia's economic development to create a self-sufficient, advanced, just, and prosperous Indonesia. Targets for 2025 included a per capita income of US$14,250–15,500, with a total GDP of $4.0–4.5 trillion.

Figure 2 suggests that for Indonesia to achieve a GDP equal to Germany's today it would have to develop a scientific workforce capable of publishing over 100,000 scientific works per year, or about 50 times the output of Indonesia in 2010. Today, there are no countries with a GDP of that magnitude that do not have a scientific force of this strength.

This point is made eloquently by Bruce Alberts in an editorial for *Science* magazine, which is reproduced in appendix A. The focus of the editorial is Arab Republic of Egypt, but the argument applies equally well to Indonesia.

The situation with respect to patents is similar to that of publications. Although patents are more closely related to productivity in industry, many companies in diverse sectors do not apply for patents (or publish papers) for business reasons. Nevertheless, the small amount of private sector expenditures on research and development is probably an important factor in the low number of patents granted to Indonesia.

TABLE 6. NUMBER OF PATENTS GRANTED BY U.S. PATENT AND TRADEMARK OFFICE, SELECTED YEARS

Economy	1992	2000	2008
Japan	23,151	32,922	36,679
Singapore	35	242	450
Taiwan, China	1,252	5,806	7,779
Korea, Rep.	586	3,472	8,731
Malaysia	11	47	168
Thailand	2	30	40
China	41	163	1,874
Indonesia	9	14	19
Philippines	7	12	22
Vietnam	0	0	0

Source: USPTO data.

5 Master Plan for Acceleration and Expansion of Indonesia Economic Development Jakarta: Coordinating Ministry for Economic Affairs, 2011.

Table 6 shows that the low number of patents granted in Indonesia has not changed significantly over recent time, in comparison with other countries in the region. The data from the World Intellectual Property Organization (WIPO), which reports patent applications by residency of applicant, show a similar picture, with nearly all the applications by nonresidents (WIPO, publication 931, 2009).

Science Education

What effect does the low input and output of the scientific community have on Indonesia's science students? Many factors affect students' performance, such as school funding, class size, and teachers' capabilities in science, technology, engineering, and mathematics (STEM).

Table 7 shows the percentage of science students at various proficiency levels in most countries. Indonesia is fifth from the bottom of the list.

TABLE 7. PROFICIENCY OF STUDENTS AT EACH PROFICIENCY LEVEL IN SCIENCE, BY COUNTRY

	Below level 1	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Finland	0.5	3.6	13.6	29.1	32.2	17.0	3.9
Canada	2.2	7.8	19.1	28.8	27.7	12.0	2.4
Korea	2.5	8.7	21.2	31.8	25.5	9.2	1.1
Japan	3.2	8.9	18.5	27.5	27.0	12.4	2.6
Thailand	12.6	33.5	33.2	16.3	4.0	0.4	0.0
Indonesia	20.3	41.3	27.5	9.5	1.4	0.0	0.0
Tunisia	27.7	35.1	25.0	10.2	1.9	0.1	0.0

Source: OECD PISA 2006 database.
Note: Countries are ranked in descending order of percentage of students at levels 2, 3, 4, 5, and 6.

These data are summarized by OECD in table 8, which ranks countries on a so-called science scale. Indonesia is tied for 50th place, albeit with three large Latin American countries, and the United States is 24th. The United States at least benefits from a large migration of some of the world's best students who cometo study at U.S. universities, and many of them remain.

The data in tables 7 and 8 are hard to evaluate because they deal with averages over the student body. Innovators are not identified by averages, and science as a discipline is led and guided by the best and the brightest. More telling might be Indonesia's good showing in competitive science competitions. The talent is there, as it certainly is in Argentina and Brazil, which tie with Indonesia on the science scale (see box 2). What is needed is a rational system for producing and supporting scientists and engineers in Indonesia, and that requires raising the quality of science and engineering education to international standards and increasing the enrollment of students in these fields.

TABLE 8. RANKING ON THE SCIENCE SCALE, SELECTED COUNTRIES

Country	Science score
Finland	56.3
Hong Kong SAR, China	54.2
Canada	53.4
Japan	53.1
Korea, Rep.	52.2
Thailand	42.1
Indonesia	39.3
Brazil	39.0

Source: OECD.

BOX 2. FRONTIERS OF SCIENCE

Despite the overall low achievement in science and engineering of Indonesia as a nation, there is evidence that at least 100 young Indonesian scientists (under 45 years old) are active and productive. They are internationally respected in their fields, and they have many international publications and patents. In 2011 the Indonesian Academy of Sciences (AIPI) and the U.S. National Academy of Sciences jointly convened in Bogor the first U.S.-Indonesia Kavli Frontiers of Science symposium for young scientists—45 Indonesian and 40 U.S. On July 11–14, 2012, the second symposium will be held in Solo, and it will be attended by the same number of young scientists. They were selected competitively through review of their track records of scientific publications in refereed journals. Most of these Indonesian scientists are involved in international joint research programs, including a new one for collaborators of U.S. National Science Foundation grantees called PEER. Because of Indonesian fiscal rules, all funds in these collaborations must be awarded to the foreign partner, who then reimburses expenses incurred by the Indonesian partner.

Raising the Low Number of Productive Scientists and Engineers

A major problem in Indonesia is the shortage of productive scientists and engineers. In the marketplace of science, the measure of results is not numbers of scientifically trained persons, numbers of laboratories, inventory of equipment, or even the amount of money or percentage of GDP dedicated to research. These are measures of input. The index of output is the measurable contribution to science, usually indicated by number of papers published in respected (peer-reviewed) publications and patents. There is an oft-stated opinion in certain circles in Indonesia that Indonesian scientists spend their time publishing papers, but the commercial products that should result are scarce. The fact is that Indonesia ranks low in research investment and low in qualifying published papers as well. These two parameters are obviously linked, and the critical linkage is the number of qualified scientists and engineers capable of conducting publishable work.

A country with a scientific community that publishes many papers in a diversity of fields is more likely to produce innovations that can be taken to the marketplace. Perhaps more important, it attracts investment and joint ventures with technological companies that are seeking a technically trained workforce, preferably but not necessarily, at lower wages than in the home country, as well as a market for their products. The size of the market depends on the country's population, but also on its spending capacity, which feeds back into the number of foreign companies attracted and willing to pay good wages. In this complex relationship, the more capable the local science and engineering community, the more likely it is that the advanced industries will hire local technical staff, and the more likely it is that these hires will produce innovations that lead to more new companies. In this second generation, more of them will be the creations of local entrepreneurs.

Steve Jobs, CEO of Apple Inc., explained it clearly to President Barack Obama when the President asked why he "exported" so many jobs to China. Apple employs 700,000 factory workers in China, Jobs said, because it needed 30,000 engineers on-site to support those workers. "You can't find that many engineers in America to hire," he explained. "These factory engineers do not have to be PhDs or geniuses; they simply need to have basic engineering skills for manufacturing. If you could educate these engineers, we would move more manufacturing plants here." (Isaacson 2011)

How can the number of productive scientists and engineers be increased? The motivation for being a scientist or engineer is to conduct research—excellent, productive, and publishable or patentable research. Young scientists and engineers must be given the opportunity to conduct research in an environment in which excellent research is rewarded. They must learn a broad variety of skills, because no one can predict the future trajectory of science and technology. Sometimes, the fields most fruitful in instilling broadly applicable scientific skills are those that seem furthest from application.[6] Students should be involved in research projects as early and to the greatest extent possible.

A national Fund that awards grants for scientific and engineering research on a competitive basis has been found in many countries to be the most effective way to encourage the best world-class science and engineering. The award and renewal of grants based on results such as publications or patents impart the value of productivity in science. Because articles are themselves competitively selected for publication by the best international journals, researchers must be well connected through international cooperation and communication to be at the cutting edge. To foster innovation, new ideas must be sought and supported. This is often done by encouraging investigator-initiated research proposals,[7] as well as the more prescriptive, results-oriented projects usually generated by requests for proposals (RFPs). And so that successful new ideas will lead to new companies and products, training, support, and facilities for entrepreneurs should be available to those whose ideas go beyond publication.

Satisfying the Need for an Appropriate Research Funding Mechanism

As argued earlier, Indonesia underperforms in research outputs in part because of its low investment in R&D, in part because of the inflexibility of its R&D financing system, and in part, or consequently, because of its low numbers of active scientists and engineers. However, there are many scientists, researchers, and engineers in the country who could contribute significantly to the nation's competitiveness and creation of knowledge if the opportunities were greater and if the funding mechanisms were more flexible and accommodating to new ideas.

As noted, the linkage is small between scientific institutions and universities and the private sector, including the small and medium-size science-based enterprises that are the centers of innovation in most countries. According to the data, few scientists are working in the private sector, and the investment in technical innovationis small. Current policies have been ineffective at stimulating the adoption of technology, despite the allowable tax deductions for R&D. The small size of most firms, the lack of clarity on what constitutes research, and the limited linkage between public research institutions and private firms are commonly mentioned as constraints to technology adoption. Most of the non-extractive industries are based on imported products with little added value. In fact, in Indonesia most industries act more like traders, and the country imports nearly all manufactured goods. There is evidently no policy toward import substitution because the tax on an imported product is waived,whereas a tariff is levied on production machinery. Additional policy incentives are needed to encourage higher added value and innovation.

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6 Nifty Fifty, http://www.nsf.gov/od/lpa/nsf50/nsfoutreach/htm/home.htm.

7 Unsolicited proposals are awarded a majority of the grants given by the U.S. National Science Foundation.

At the same time, the current public financing mechanism provides very little incentive for public R&D institutions to collaborate with the private sector. For example, the current fiscal law states that all government entities must be fully financed by the national budget, and the budget appropriation is supposed to be adequate to conduct all research activities. Therefore, the status of public R&D institutions as government entities that comply with fiscal law requires that any funds collected from private or external sources be submitted to the Ministry of Finance as nontax revenue that can be reclaimed only through line items in the yearly national budget process. This means that scientists who wish to collaborate with foreign colleagues in a newly funded project must ask their collaborators to accept the grant and reimburse the expenses of the Indonesian partner, which is hardly a basis for cooperation among equals.

One of the major constraints to creating a new R&D program in Indonesia that affects all public institutions is the government-based rigid line-item annual funding mechanism. Current Indonesian fiscal law and regulations discourage multiyear research programs, although they allow year by year renewal.And they offer no flexibility in the use of funds. In some programs, acquisition of equipment is not permitted. Furthermore, bureaucratic procedures effectively limit research work to only six months of the year (May–October). Allocations are announced in January, but funds are not disbursed until April or May, and highly detailed final reports, which may take a month to prepare, are due in November. Some scientists complain that they are forced to lie in order to report the progress on which future funding will depend. They frequently request funds for projects already completed in order to have progress to report after six months, and use current funds for next year's project. Obviously, they cannot remain at the forefront of their fields with this strategy.

One deterrent to increasing the number of working scientists and engineers is the formal career path system found in government R&D institutions. As government entities, they must comply with the civil service law in recruiting, employing, and promoting researchers. Young researchers just setting out in their careers must choose between following a technical research path or an administrative career path. The administrative career path provides much better incentives and remuneration than the technical research career path, and so many young trained researchers are steered away from the laboratory before they have had a chance to apply their expensive training to solving national problems. The government has tried to create a better and more promising technical research career path, but the incentives and remuneration are still far below those of the administrative career path.

Reasons for the poor performance and ineffectiveness of science and technology policy also lie in the lack of accountability and merit review in the science and technology institutions. Although the Ministry of Research and Technology (RISTEK) has the mandate to develop and coordinate national science and technology policy, it is currently constrained in its capacity to influence policy implementation. Its most direct influence is its role as the coordinating agency for the seven LPNK non-ministerial research institutes, which are the main executors of government policy priorities in science and technology. But funding to government research institutions is allocated on a noncompetitive basis and through funding formulas not directly linked to the productivity of the institutions or to a coherent R&D strategy within the context of broader government priorities. This system removes from RISTEK's arsenal a powerful budgetary weapon for implementing science and technology policy and providing incentives for increased productivity.

The need for reform is apparent, and the government is placing innovation at the center stage of economic policy. But the crucial link among innovation, entrepreneurship, and the number and quality of scientists and engineers able to carry out novel and original research projects, as well as mission-oriented projects, has not been recognized. Consensus building among key stakeholders around the importance of innovation and discovery is still needed to guarantee that reforms will take place.

Objectives of an Indonesian Science Fund

Three major objectives are proposed for the Indonesian Science Fund.

Enable More Productive Fundamental, Applied, and Priority Research

The principal goal of a new Indonesian Science Fund would be to elevate the overall quality of Indonesian research and make it more productive. This in turn would be expected to result in more publications and patents, in a more productive scientific effort in all areas, and, ultimately, in more innovation, more science-based enterprises, and more direct foreign investment and joint ventures in technological areas. The history of recent Asian economic development, especially among the Asian "Tigers," India, and China, lend credence to this scenario.

The relatively low rate of publication in the sciences is not a direct reflection of the number of scientists and engineers in Indonesia, which table 1 suggests is close to 40,000, or of the level of investment in science and technology. Some smaller countries with far fewer scientists and engineers are leading Indonesia in scientific output per dollar of investment.[8] The problem is more systemic and has to do with the allocation of resources, including human resources, and the research environment, which may not be conducive to the freedom and autonomy necessary for innovation. As described earlier, the career track for scientists is rigid, and it limits opportunities for researchers. It also limits risk, and scientists can often carry out little productive research without penalty. Advancement in scientific careers in universities, as well as in the government's LPNK research agencies, should be based on quality of output and contribution to knowledge or technology. A competitive funding resource based on excellence, originality, and capability would provide incentives and rewards that furthered these goals.

[8] Taken together, figure 1 and table 3 show that Indonesia invests about $1 billion a year in R&D and that Indonesians published 13,000 scientific papers during 1996–2010. Thailand invests roughly the same, but it published 4.5 times as many research papers; Malaysia $2 billion and 4.2 times as many papers; and Singapore $5.6 billion and over 8 times as many research papers.

The culture of science encourages scientists to allow their curiosity to identify new research questions. This is not a luxury for rich countries but the way new ideas emerge, and it is important to both applied and fundamental science. Even many industries give scientists somewhat free rein in choosing a research problem, because they know it leads to more new ideas that frequently lead to application.[9] Nevertheless, there is also a national interest in encouraging and supporting mission-oriented research on certain topics of national priority.

Applied research related to national goals can be encouraged by means of special grant programs defined by requests for proposals targeting certain priority problems that would be managed separately from unsolicited proposals. The RFPs can be tailored to the particular problem, and they can be prescriptive, in order to encourage a cohort of researchers working along similar lines, or they could be broad to encourage fresh ideas. Multiple grants covering similar methodologies could be awarded to stimulate competition or cooperation. This approach may be particularly effective in agricultural and health-related research, where similar trials in different environments or different populations can yield results greater than the sum of the trials. Targeted grants may also be used to foster cooperation between companies or LPNKs and universities.

In the competitive environment of international science, laboratories require modern scientific equipment, and continual upgrading of equipment should be expected. However, scientific equipment is expensive, and it should be managed in a way to maximize use. Sharing of equipment would be an effective mechanism, and the ISF may elect to receive special joint proposals from multiple institutions to justify acquisition of expensive equipment. Alternatively, ownership of laboratory equipment may revert to the ISF at the end of a project so that it can be transferred to and used by other grantees.

To improve Indonesia's competitiveness in international science and technology, some large, expensive research facilities used by multiple research groups could be acquired, owned, and operated by the ISF itself. Use of the facilities could be allocated on a competitive basis and included in research grants, or they could be made available for a fee to researchers or private companies that have other sources of funds. Examples would be oceanographic research vessels, powerful computers, telescopes, and electron microscopes.

In the science and technology race, second place does not bring the same rewards. So that researchers are current with the latest developments in their fields, travel grants to attend international conferences or visit overseas laboratories should be included in research grants where appropriate. Where it is necessary to use unique research facilities that are only available abroad, the cost of travel and fees for usage might be included in grants as well.

9 For many years, the AT&T Corporation in the United States operated Bell Laboratories in order to allow their top scientists to work in almost total freedom. It was called the home of Nobel Prizes, and produced many valuable devices, including the transistor. Consistent with the spirit of the laboratory, AT&T did not patent the transistor, but nevertheless profited by avoiding billions in license fees.

Increase the Pool of Trained Research Scientists and Engineers

For success in encouraging innovation and the creation of science-based enterprises, an enlarged community of trained scientists and engineers is essential. They will provide the population from which the rare innovators will emerge, and they will fill the technical jobs in the enterprises the innovators create. The availability of research support and of fellowships or research assistantships for students can effectively attract students to careers in science or engineering, and encourage good scientists and engineers to remain active in research. Graduate or postdoctoral fellowships that allow young scientists and engineers to advance their research programs at Indonesian institutions should be part of most grants, and some should also be available to individual applicants directly so they can choose which Indonesian research group to join. The addition of funds for research should help to correct the imbalance between the research funds awarded to universities and those given to government institutes, and provide more resources for student researchers. The efforts of the ISF should be complemented by strengthening the career ladders for researchers in universities and government agencies.

Science education is itself an active field of research, and important gains have been made in recent years. Neurophysiologic research and computer training applications that have not yet penetrated educational practice have led to greater understanding of the learning process, and inquiry-based methods are producing good results. Box 3 suggests possible actions for the ISF.

BOX 3. STANDARDS FOR STEM EDUCATION

The U.S. National Science Foundation has partnered with the U.S. National Academy of Sciences and other nongovernmental organizations to prepare standards and model curricula for primary and secondary schools that are now being applied in schools throughout America. ISF could help to develop and implement similar programs for Indonesia. Science education at the primary and secondary school levels is crucial for recruiting and preparing future scientists and engineers. If incoming students do not have a sound background in STEM (science, technology, engineering, and mathematics), universities will find it difficult to produce good scientists and engineers.

Foster Entrepreneurship and Innovation

There are many successful models of programs to train and support entrepreneurs and promote entrepreneurship (Quadir 2012, 1445). Some of the most successful are university-based, where they assist students and faculty to develop and market the results of their research, sometimes to the great benefit of the universities themselves. These models involve incubators where new businesses can operate and share facilities and consult with experienced businessmen and women, and where they can gain access to venture capital and other resources. Grants can be given to universities to establish incubators to serve the academic community and others.[10]

The ISF also might collaborate with the Ministry of Industry and the Ministry of Cooperative and Small and Medium Enterprises to fund joint programs that assist science-based enterprises, or that link enterprises with university-based engineers and scientists. Such programs often involve cost sharing between the Fund and the enterprise.

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[10] The U.S. National Science Foundation has a new program, Innovation Corps, that awards $50,000 to scientists to market a product based on their NSF-funded research. The scientists are paired with experienced entrepreneurs and graduate students to carry out market research on the new product. They are then directed to venture capitalists or other government programs for first stage financing. (Mervis, 2012. p. 756).

Funding Instruments, Operating Principles, and Organizational Structure

Funding Instruments

Different funding instruments are needed for the different objectives of the Fund. Each would be directed at achieving results related to the specific objective, but any grant or award to an institution could include more than one of these instruments.

All grant funds should be administered by the host institution in a way that the grant-related expenditures can be reported and audited independently of other institutional funds. The ISF must be immediately notified of any change in the principal investigator, and if the project is to continue, a replacement principal investigator must be approved by the ISF. Similarly, a grantee wishing to move and transfer the grant to another institution must have the approval of the ISF, which may demand the concurrence of both institutions.

Overhead charges could be added by the host institution to research grants to cover indirect costs, including the cost of administering the grant. The ISF program should not impose a burden on universities and other grantee institutions, but rather provide an incentive to deans and managers to encourage their researchers to seek grants. Overhead charges are intended to cover the extra cost to the institution of hosting the grant. These range from the extra cost of cooling active laboratories to the costs associated with accounting for funds and maintaining equipment, and even possibly the cost of replacing the classroom time of a professor who is devoting part of his or her time to research. The rate of overhead should be subject to periodic audit by an agency selected by the ISF.[11]

[11] It is the practice in the United States for one agency to be selected to carry out all audits of overhead rates for all grantees and contractors of U.S. government agencies, and grantee institutions must apply to that agency (currently the Office of Naval Research) for an approved rate before applying for grants.

Each funding instrument will be directed toward achieving results related to a specific objective, but any grant or award to an institution can include more than one of these instruments:

1. **Principal investigator research grants.** The primary funding instrument for researchers will be the research grant, awarded to the host institution for the exclusive use of the principal investigator. It will be awarded on the basis of a proposal, either unsolicited or in response to a request for proposal prescribing the type of research to be performed and some of the goals and terms of reference of the study. It will specify a fixed time period for completion and may involve participation in a multicenter study or collaboration with other institutions. It also may be conditional on including students in research activities via research assistantships.
   Review criteria: Capability of research team, importance of problem, potential for success of the methodology, probabilityversus impact of success, benefit to students.

2. **Travel grants.** These grants are awarded to individual investigators for participation in a conference, a visit to another laboratory for a short period, either abroad or within Indonesia, or a visit of a foreign scientist to a laboratory in Indonesia. The grant would be awarded to the host Indonesian institution.
   Review criteria: value of conference attendance or visit to applicant, potential benefit to Indonesian science.

3. **Student fellowships.** These grants are intended to assist students who are working toward advanced degrees in a science, social science or engineering field. The awards are based on applications responding to announcements from the ISF that may request information on the plan of study and personal references. Another award for students will be the research assistantship, which normallyis part of a research grant, in order to support students who dedicate a specified amount of time to the grant-supported research.
   Review criteria: capability of student, benefit to research project (for research assistantship)

4. **Industrial cooperative fellowships (ICFs).** These awards would enable a student to work within a private company or LPNK on a project related to the student's interests. The application could be submitted by either the university or the company or LPNK, but the award must have the agreement of both. The award goes to the host company, which pays the student the salary or stipend specified in the award. Companies may apply for several ICFs at once, but each will be awarded after the recruitment of the student. These opportunities are usually announced publicly and a deadline set for application so that the term of the award will coincide with a semester at the university. The ICF may be conditional on the assurance that the facilities and resources for the research are available from other sources such as ISF research grants.
   Review criteria: potential learning benefit to student in science or engineering.

5. **Cooperative research awards.** These awards support joint research by industrial or LPNK scientists and university scientists and generally have the same characteristics as research grants, including application from a principal investigator, usually associated with the company. The awards are considered to be a form of collaboration between the company or LPNK and the ISF, with the ISF paying the costs of the university scientists and the company paying its own costs.
   Review criteria: Potential benefit to the technical capability of the company, capability of university team.

6. **Entrepreneurial support grants.** These grants are awarded to universities to develop programs to assist students, faculty, and others to market and commercialize original inventions, products, or other intellectual property. The support may entail patent advice, incubator facilities, meetings with experienced business managers and venture capitalists, and shared equipment. Funds should not be used to acquire capital assets in the new companies. Proposals may require cost sharing with investors or host institutions.
   Review criteria: Potential benefit to entrepreneurs and innovators, benefit to students.

7. **Grants for educational research.** These grants may complement principal investigator research grants on educational topics and enable new methods, curricula, or syllabi to be tested in schools. The grants are awarded to collaborations of the researchers and a teacher, or they may be awarded to a primary or secondary school alone, with a teacher as principal investigator.
   Review criteria: Potential impact on science and engineering education, benefit to participating schools, teachers, and students.

All these instruments are grants, not contracts. The project is approved based on a proposal that sets forth the problem, the capability and experience of the research team, and the methodology proposed for solving it. The grantee will have the freedom to change direction (without additional funds) in response to research findings reported to the ISF. The success or failure of the project will be the responsibility of the grantee, and, provided the work plan proposed (or as modified) is carried out as planned, any reward or penalty from the ISF will be limited to its impact on future grant applications.

The Fund should make an effort to fund integrated projects, with research, foreign travel, equipment, training included in one proposal, not many separate proposals on the same topic in a single institution. Such an approach will avoid the double jeopardy of having important parts of a project not funded, as well as reduce the need to write, review, and fund multiple proposals for the same project.

Funding will be provided in yearly increments. To receive the next year's tranche, the investigator must submit an annual report, following guidelines provided by the ISF. At the end of the project, the institution must submit a final report, including all technical details, research findings, and financial accounting in a timely fashion. The final report may be modified as further publications, patents, products, student degrees, and such develop, and may be cited in future grant applications. In most circumstances, reasonable no-cost extensions of the project should be routinely granted, provided there is evidence of ongoing activity.

Operating Principles

The ISF is designed to provide merit-based funding of research projects in science and engineering, including evidence-based social science and educational research. The projects may also include efforts to develop products and services based on research results to prepare them for marketing and investment. The ISF should not itself invest in commercial products or services, which could lead to conflicts of interest. The grantees may be individual investigators or a consortium of researchers at the same or different institutions. In order to advance the excellence of research programs, the ISF may lease or purchase scientific equipment for a single laboratory or for a facility that is used in common by many grantees.

Proposal Review

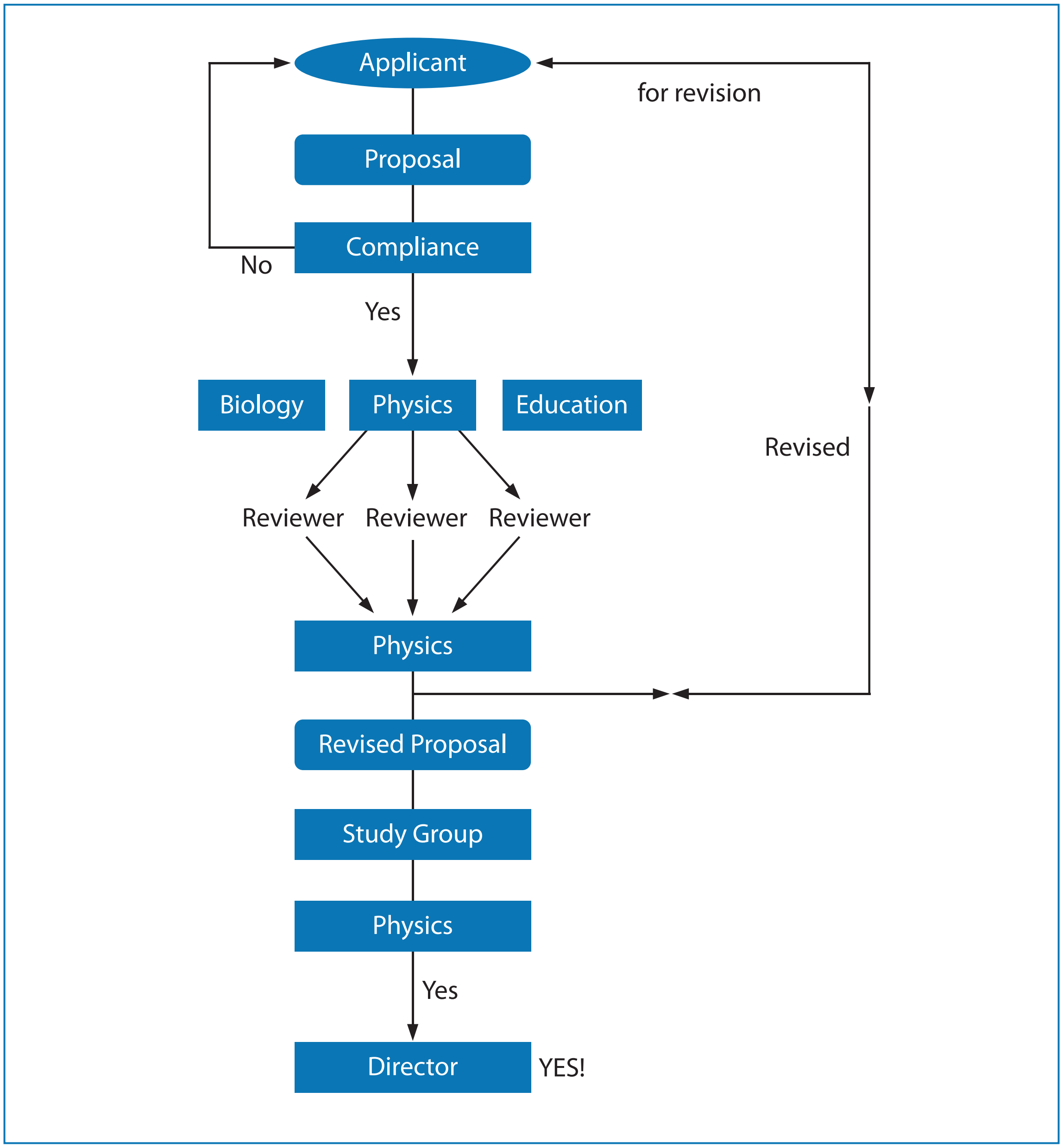
The objective of merit-based proposal review is basically to evaluate the probability of success of a not-yet-realized project that is based on an untested hypothesis. The methodology for project selection considered by the worldwide scientific community as most effective for this seemingly difficult task is scientific peer review. This entails written review of proposals, usually anonymously, by scientists who are expert in the subject matter of the proposal. The reviews are generally shared with the applicant, and the applicant is often given an opportunity to respond or amend the proposal. The actual decisions on funding are the responsibility of paid, scientifically trained ISF staff, who are accountable for the fairness of their procedures. The final decisions are subject to review and approval by superiors. When the paid staff members are themselves scientists who are temporarily seconded by their institutions to the ISF for a fixed period, the organization gains a democratic, run-by-scientists-for-scientists spirit. But the most important quality of the peer review procedure is the perception among the public and the scientific community that the selection is fair, and scientific merit is the primary factor considered.

Some factors in the design of a peer review process may be of particular importance to a country like Indonesia. In some fields, the active researchers in Indonesia are few and well known to one another. An anonymous review of a proposal by available Indonesian scientists in such a field may be difficult; for example, they might all be at the same institution. In these cases, it may be necessary to solicit some reviews by foreign scientists. That would require that proposals either be submitted in English or be selectively translated. The latter choice may be criticized by those whose proposals are rejected (they may claim the translation was poor!), and so it may be found advisable to request that all proposals be submitted in English. Many national science foundations help each other by providing reviews of proposals that are submitted in a language used widely in academic circles, and some national science academies are willing to assist in the process. Participation by foreign reviewers also serves to underline the adherence to international standards in scientific review.

Because every proposal must be managed by a program manager who understands the science, the staff is usually organized by scientific discipline, such as physics, biology, and engineering. Unless the Fund becomes very large, related disciplines will inevitably be lumped together to accommodate the finite staff. Physics will embrace astronomy, geology, and materials science, along with the traditional physics specialties, and biology will include biotechnology, zoology, botany, biodiversity, and some marine science.

The system used by many scientific research funds is to send a new proposal to a small number of scientists who are expert in the particular field or technique for anonymous written reviews, then assemble a "study group" with a broader view to meet to make funding recommendations on groups of proposals (see figure 3). For example, a proposal on nanotechnology applied to improving drug performance may first be given an initial screening for compliance with the rules of the program and classification of content. It would be sent to a biology program manager because of its subject matter. The staff biologist might send it to two nanotechnologists and a pharmacist for written reviews to judge the methodology and the competence of the research group. If there are other proposals in the pharmaceutical area, a study group of scientists chosen from government, universities, and private sector would be formed to review all of them together. The proposals, each accompanied by two or three written reviews, would then be considered by thestudy group on drug performance to weigh each proposal's probability of success against the others. The study group would be asked to prepare a list of the proposals in order of merit, while a staff scientist records the discussion of each project. The staff scientist would then calculate how many on the list can be funded with the funds allocated to that field. He or she must take into account other mandates that might be applicable, such as funding a few proposals from young scientists or first-time applicants, or favoring proposals from eastern Indonesia.[12] A memo summarizing the written reviews and the rating of the study group would be prepared to justify every decision.

FIGURE 3. PATH OF A SUCCESSFUL PROPOSAL IN PHYSICS



Note: Applicants are given a chance to revise the proposal after reading the reviews if the submission is received early enough in the review cycle.

[12] A staff scientist who any personal connection with the applicant or the applicant's institution must recluse himself or herself from this process and pass the proposal to another staff scientist for a decision.

Fortunately, during the last decade the entire grant process—announcement of grant opportunities, links to grant forms, submission, review, and response to review—have benefited from advances in computer and communications technology to the advantage of both applicants and granting agencies.

A common difficulty when introducing competitive peer review to a community of scientists unused to these procedures is lack of proposal preparation experience (Greene 1991). This difficulty will face both applicants and the Fund, which must select the best research projects based on scientific merit and originality, not grant-writing ability. A set of skills, collectively called "grantsmanship," helps the applicant to describe the proposed project in an informative way and in the best light. These skills can be learned, and perhaps even learned best online by guided instruction and example.

Allocation of Grant Funds

Increasingly, science funds are finding that when many of the proposals received are unsolicited—that is, not in response to well-defined RFPs—the policies on priority areas are most conveniently implemented though allocation of funds. For example, one year there may be as many proposals received on computer science as public health, but if policy requires that emphasis be placed on public health, then more money can be allocated to the public health area, and more grants can be awarded there without the ISF having to place restrictions on applicants. There alsomay be a national interest in favoring certain groups, such as applicants from Eastern Indonesia for certain types of grants and in setting aside some funds for projects with a high risk but potentially large payoff. (This observation is based on the speculation that a proposal from Albert Einstein would not have been accepted—or understood—by many peer reviewers of his age, and so a separate fund can be allocated for proposals that seem to qualify.)

It is not feasible to allow proposals in different disciplines managed by different staff using different study groups to compete against one another, so allocations would be decided in advance by a higher body within the Fund for each field or discipline. Adjusting funding allocations among disciplines can move the research enterprise in new directions and may be a useful policy instrument. Funds are also set aside for programs on targeted priority areas, to be announced with special requests for proposals to offer guidelines and distinguish them from the unsolicited proposals.

In every discipline, there must be normalization between average size of grants and number of grants, the two factors of the total grant budget. These cannot always be set ***a priori***, but it may be advisable to design a special program for large grants so that they do not distort the overall research effort. There should also be a set-aside for first-time applicants, who are at a disadvantage both in grantsmanship skills and name recognition, in order to reach out to the next generation. The same may be said of high risk or unusual proposals, as mentioned earlier.

Staffing

The staff of the ISF should be a combination of permanent and temporary professional staff. The permanent staff will provide the skill, institutional memory, policy direction, management, and training for new staff. The temporary staff, who may be recruited for one- or two-year periods from the universities, laboratories, and institutions that are the clients of the foundation, will provide the link with the scientific community and the current knowledge of the research fields. Care must always be taken to avoid decision making by temporary staff that affects their home institution and colleagues.

Financial Accountability

The Fund will have a responsibility to its own donors, the government, and the scientific community to account for the funds it disburses. This responsibility is passed on to each grantee, and will require a set of uniform standards for the management of grant funds. Because some of the contributors to the ISF are likely to be international, these standards must conform to international norms, and accounts must be available to international auditors. The following issues must be among those considered:

- Accountability systems for grant funds: should they beheld in separate accounts or mixed with other grantee institutional funds?
- Approved management systems for inventory, maintenance, and control of donated equipment
- Mechanisms for disposal or transfer of equipment and materials at the end of grant period
- Requirements for internal audit
- Requirements for financial reporting
- Institutional review of projects involving human subjects
- Rules for investigation of accusations of ethical malfeasance
- Regulations for protection of intellectual property: securing licenses and respecting patents where applicable.

The Fund should publish and distribute clear guidelines for applicants and rules for grantees.

Some research institutions, even some mature and prestigious ones, will not have resolved all these issues to the satisfaction of international auditors. Deficiencies or deviations will be more easily resolved before grants are awarded than in response to auditors' queries. For large institutions with many ongoing programs, or for those required to conform to other regulations—for example those of the Indonesian government where concordance is not possible—it may be necessary to set up separate procedures, with separate bank accounts and accounting systems, for grants awarded by the ISF.

Reporting requirements deserve special mention. Among the issues most frequently cited by Indonesian scientists is the onerous reporting requirement of government agencies. Long, detailed report formulas sometimes require a month to complete, and in early stages of a project transmit little valuable information. For other than a final report, the Fund should limit the information reported to that demonstratingeffort or achievement, that revealing problems that might require follow-up, assistance, or intervention by Fund staff, and that concerning delays or other changes in the research plan that may require justification and Fund concurrence. Changes in the research plan that are the result of new findings may be a positive development to be supported by the Fund.

Financial accountability of the Fund itself consists of two components: how well it follows its own procedures in grant making and disbursal of funds, andhow well it audits the accounting of the grantee institutions.The grantees' accounts may be audited by internal auditors in each institution and checked at random or for cause by auditors contracted by the ISF.

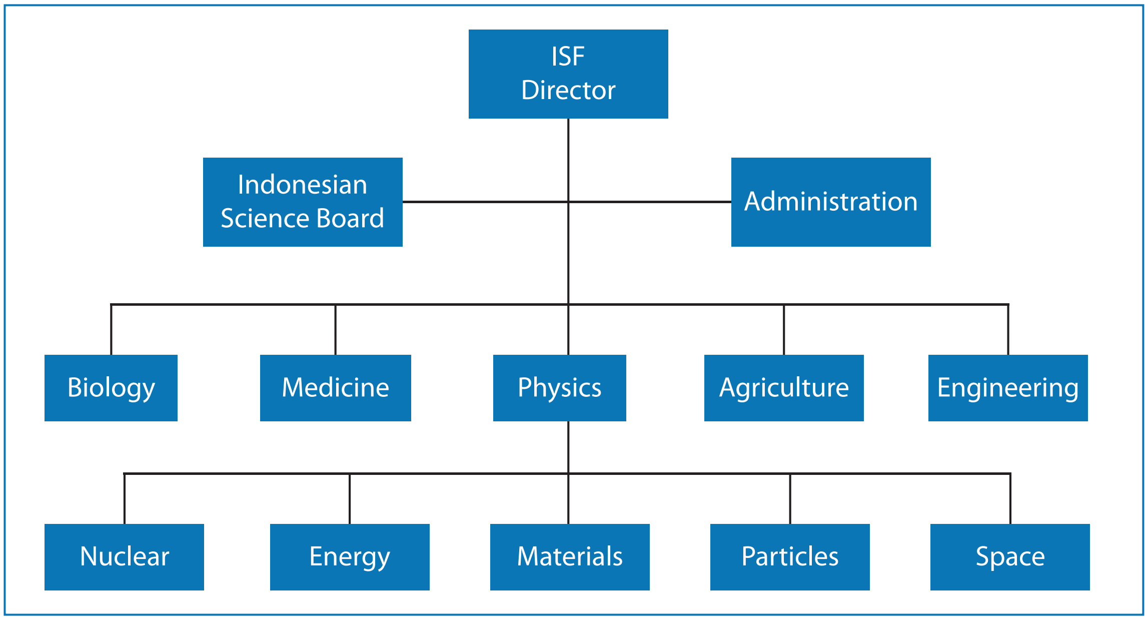
Organizational Structure

A standard organizational structure for a research granting agency would be similar to that of a corporation: a director and executive office at the top, the policy-making board of trustees attached to the director's office, and the program staff that recommends decisions to the director, organized by disciplines or sectors below (figure 4).

The applicants could direct their proposals to the disciplinary sections such as physics or biology; multidisciplinary proposals would be assigned at the discretion of the ISF. Those responding to published requests for proposals would be directed to the requesting section. The Fund should not label proposals according to whether they seek pure knowledge (fundamental) or application to problems (applied) for the complex reasons discussed earlier. Instead, it should assign all proposals for processing to staff members who are knowledgeable, and in science and engineering that means specialized training to the PhD or equivalent level. Most decisions on funding would be made at the program staff level, because the director, with a limited technical staff, will not have the breadth of knowledge or time to do anything but correct gross errors. It is essential that the rules of procedure be clear and strictly enforced to avoid issues of perceived or real bias in award of grants. It would be detrimental for any senior program officer to be considered the czar of any particular program or discipline, able to make personal decisions on award of grants.[13]

The system for allocation of funds must parallel the staff organization. Although it is reasonable for a staff scientist to manage more than one grant program—physics and energy, or biology and marine science, for example—it is difficult for two programs with different staffs to compete for the same resources without conflict in the recruitment of a study section and selection of grantees.

FIGURE 4. ORGANIZATION OF THE INDONESIAN SCIENCE FUND



Note: Staff are organized into disciplinary sections. Under each will appear applied science programs.

[13] At NSF, most program managers are temporary staff borrowed from universities for one or two years; there is little opportunity to build an empire before they are back in their laboratories applying for grants themselves.

The role of the government is an important issue. Some have proposed that the Fund be fully funded by international and domestic donations and government to a level high enough to form an endowment that would maintain the program in a sustainable way. In such an event, it would be highly important that there be continuing participation by the government, both in governance and in financial support. If it is successful, the Fund will have a significant impact on Indonesia's competitiveness and economic development, and would be an effective tool in implementing the government's economic and education policies.[14]

Appointment of the ISF director and science board by the president would make the ISF responsive to government policy. Terms of office longer than the term of the president would help to free the ISF from short-term political pressures. The Fund would, then, be governmental but not part of any particular administration. A six-year term for the director and staggered six-year terms for all board members of the ISF would help to insulate it from five-year elective politics in order to preserve its independence, but would align its priorities with those of national policy. The government could allocate extra funds for specific research goals to implement special policies. Box 4 describes the organization of the U.S. National Science Foundation.

BOX 4. U.S. NATIONAL SCIENCE FOUNDATION (NSF)

In the United States, the NSF is an independent government agency—that is, it is not a part of any department (ministry). The director of NSF is appointed by the president of the United States, and the director's six-year term of office is longer than that of the president (four years). But a newly elected president rarely replaces an NSF director. The members of the National Science Board (NSB) are also appointed by the president for a six-year term, with a third of the board replaced every two years. The director of NSFand the NSB members must be confirmed by the U.S. Senate.

Outreach and Evaluation

Evaluation of the Indonesian Science Fund may be carried out in part by inviting an international "visiting committee" composed of scientists and the officials of similar institutions in other countries. An evaluation plan must be prepared and acceptedin advance by the visiting committee, and perhaps by key donors, including the Indonesian government. This process would demonstrate that research in Indonesia is maintained according to international standards.

As with any other endeavor, it is important that the output of the Indonesian Science Fund be evaluated and publicized. A monthly popular journal focused on students and highlighting some of the most interesting projects would be useful. A Fund website could provide scientists, particularly possible grant applicants, with information on programs, deadlines, and opportunities, and be a source of instruction on preparing grant applications.

[14] At the NSF, the allocation decisions are proposed by the director and approved by the presidentially appointed National Science Board. In general, at NSF the allocations for each discipline are made proportional to the number of proposals received in the previous year. This formula maintains quality of grants across disciplines in the sense that the same proportion of proposals is funded. But funds are shifted between directorates for special NSF-wide initiatives.

Evaluation of the state of Indonesian science and engineering and their impact on the economy will require information and statistics on Indonesian science and technology related to numbers of scientists and students of science and engineering, published papers, patents, R&D in the private sector, and other measures of discovery, innovation, and entrepreneurship. The U.S. National Science Foundation annually publishes *Science and Engineering Indicators*, which reports on the impact of science and technology on the economy, education, and society, and compares the United States to other countries. In 1993, the first *Science and Technology Indicators Report of Indonesia* was published by LIPI, with the assistance of the U.S. National Academy of Sciences and consultants from NSF. The second report was published by LIPI in 1996.

These reports contain the information needed to track the indicators of science and technology over time, thereby revealing whether the number of scientists and engineers, patents and publications, and science-based enterprises have increased, and the impact of science policy on the economy and the research enterprise. It would be appropriate for the Fund to support or itself produce a periodic Indonesian science and technology indicators report. Although it will be many years before the impact of the ISF itself is seen in these indicators, they will provide a good measure of change in Indonesia's standing among the world's countries.

Institutional Framework

One of the characteristics of a healthy national R&D funding system is that multiple sources of funding are available to researchers. Funding agencies can have different priorities, different rules and requirements, and different funding calendars, and it is important that researchers with different goals or timetables have several options. It would be of little advantage if the creation of an ISF reduced the program of action of the dedicated mission agencies such as LAPAN or BATAN, or of LIPI, with its body of expert researchers who maintain the system of laboratories and facilities undertaking research in many fields around the country. The Fund should be one element of a multifaceted R&D system, tasked with increasing the quality of science and engineering at a fundamental level, increasing the number of scientists and engineers in industry and academia, and forging new links between the scientific enterprise and industry.

According to the international evidence, most countries, led by the OECD and EU member countries, are moving toward quasi-autonomous professional granting agencies that rely on independent merit review processes to support research grants and development projects in both the private and public sectors along the lines just described. This could be done in Indonesia in one of three ways:

1. This task could be assumed by a government agency, possibly the Ministry of Research and Technology.
   Pro: Some of these institutions already have facilities and research staff familiar with granting procedures. They also have project accounting mechanisms in place. Start-up time could be reduced.
   Con: The creation of a granting facility within a government agency would require major revisions of budgetary law and regulations. The most important barrier would probably be the provision mandating that any funds collected from private sources be submitted to the Ministry of Finance as nontax revenue and only be reclaimed through line items in the annual

national budget process. The restriction to one-year grants and the limitation on the purchase of equipment would have to be modified as well, along with the cumbersome budgeting and reporting requirements that limit flexibility and freedom of action. Furthermore, each most government agencies have dedicated intramural research programs related to its mission. Confusion about the participation of the internal research staff in the national program and competition for research funds could damage the effectiveness and the reputation of the competitive program.

2. The task could be assumed by a nongovernmental organization.
   Pro: The problems associated with government agencies would not be a factor.
   Con: A private Fund operating in Indonesia as a principal funder of science and engineering could present problems of a different nature, whether it relied on continuing private donations or a sustaining endowment. The government would have no direct influence on the policies and programs of the Fund, and the Fund might not coordinate its program with national science and technology policy. This arrangement could generate friction with a future government, to the detriment of the nation's science and engineering.

3. The task could be assigned to an independent, dedicated agency with partial government funding and the capacity to raise other funds from private and international sources.
   Pro: This agency could be housed under an existing independent government-funded institution, while remaining separate and autonomous. An autonomous Fund under the umbrella of an independent institution, with significant government participation, could avoid the pitfalls associated with government agencies while providing a voice for government in policy decisions. Its director and board of trustees could be selected by government, scientists and engineers, and others in a manner that would preserve independence and avoid tight political control, while the agency maintains an active dialogue with government policymakers. The government-supplied part of the budget could carry the recommendations and priorities of the parliamentary DPR, and still leave room for receiving additional funding for other beneficial activities. In this model, ISF funding could include an endowment fund, a periodic government appropriation, participation by philanthropic organizations, long-term funding commitments from international agencies, and other donations.
   Con: The budget and scope of activities are likely to be much greater than that of the host institution, and may overwhelm its staff and overshadow its primary purpose. It is important that separate facilities and a separate staff be provided for the ISF, so that the active links between the two entities be as tenuous as possible, so long as the rights and privileges of the host institution are transferred to the ISF. Box 5 describes the Thai Research Fund, an independent government agency in Thailand.

BOX 5. THAI RESEARCH FUND

A representative of this model is the Thai Research Fund. It is an independent, non-governmental Fund that receives financial support from the Thai government and other donors, and it has its own endowment fund. The role of this Fund is similar to the role of NSF: it must be responsive not only to government policy but also to the global issues affecting the quality of human life that concern international donors. More information at www.trf.or.th

Recommendations

There is near unanimity among scientists in Indonesia that the country is not producing science or innovation at the rate it should. Primary evidence is the low number of publications and patents. Scientists believe the cause lies in the difficulties encountered in securing support for research projects and the inflexible budgeting and reporting system in place. Less frequently mentioned are the heavy teaching loads of university researchers and the higher salaries offered for non-science careers in the LPNKs, both of which drive scientists away from research. The comparative data published by international sources confirm that Indonesian researchers are less productive than those in most comparable countries per dollar of research funds invested, and that Indonesia does not fall within the group of countries of its size and resources in the measures of national productivity for science and technology. (See appendix A for an editorial by Prof. Bruce Alberts of the University of California, San Francisco, currently editor of ***Science***. His discussion pertains to Egypt but the issues he raises are also pertinent to Indonesia.)

Indonesia does not have the financial infrastructure in place to support cutting-edge science and technology. Nor does it have an infrastructure in place to allocate and disburse funds to researchers, provide facilities for research, or maintain a state budgeting system that would allow the flexibility needed for scientific research. Beyond these issues lies the larger one of a low national investment in research and development. As a fraction of GDP, Indonesia's gross R&D investment is almost too low to appear on the published charts.

These problems can be addressed together, as a system, by creating an autonomous Indonesian Science Fund that,on a competitive basis, would directly supply scientists and engineers with funds for world-class research. It would also point out obstacles and would require, as a condition of awards, the institutional support researchers need for increased productivity.

RECOMMENDATION 1

An Indonesian Science Fund should be established under the auspices of the Indonesian Academy of Sciences (AIPI).

AIPI is a non-governmental entity, but established by a Law of the Republic of Indonesia (Law No. 8/1990) that explicitly stipulates government financial support as well as the freedom to seek non-government funds. As such, it is exempt from the financial regulations that inhibit fundraising and multiyear planning. AIPI has a small office in central Jakarta, in addition to the facility at its headquarter in Serpong.

The ISF should be housed in its own building facility in Jakarta. The ISF director should be elected by the AIPI General Assembly and appointed by the President of the Republic for a non-renewable six-year term. An Indonesian Science Board of 12 members should also be elected by the AIPI General Assembly and appointed by the president for non-renewable six years terms. They should have staggered terms so that every two years one-third of members are replaced. It is highly important that the terms be non-renewable to avoid the perception of bias in the award of grants toward members of the bodies that elect the director and Board.

Initially, the ISF should have four discrete modes of action, all initiated by proposals received from applicants:

1. Unsolicited research proposals from scientists, social scientists, and engineers. These would be evaluated and assigned to one of the disciplinary or applied science programs to compete with similar proposals.

2. Applied science proposals in response to requests for proposals on one of the priority areas designated by the Indonesian Science Board. These would be evaluated together with others applying to the same program.
   One of the early RFPs should request proposals for facilities to support entrepreneurship. These may be based on one of the many successful models applied in other countries (Quadir 2012), or one unique to Indonesia.

3. Proposals on science education. This is essentially an applied science program, but one that will be continuing in an effort to develop new curricula, teaching techniques, and course materials to increase the number and quality of science students in primary and secondary grades.

4. Fellowships for graduate students applying for advanced science degrees in Indonesian universities. These would be high-prestige fellowships that would persuade some of the best students to remain in Indonesia for their graduate studies.

There should initially be one grant cycle per year, with an announced deadline for review by the study groups. Those who apply early will have an opportunity to revise their proposals and resubmit before the deadline after seeing the written reviewers' comments. Staff should be recruited and trained as needed to manage the proposals and programs submitted.

In addition to a core of permanent staff, some of the program managers should be on loan from universities and LPNKs for two-year terms. These managers would propose to the ISF director which applicants should be awarded grants, the highest responsibility in the Fund. The constant rotation will give scientists a feeling of participation and prevent the growth or perception of permanent bias in any programs.

An estimated annual budget of 414 billion rupiah (U.S.$ 44 million) is proposed in Appendix B.

RECOMMENDATION 2

Remove the requirement that any funds collected from private or external sources for research purposes be submitted to the Ministry of Finance as nontax revenue that can only be reclaimed through line items in the annual national budget process. Permit recipients of ISF grants to utilize the funds outside the annual budget process for purposes described in the grant, including multiyear projects.

The present system does not permit researchers to seek funds for research projects from international or domestic sources without putting at risk the funds already received from their organization. This arrangement often forces them to collaborate with foreign researchers in a way that the foreign partner receives all funds and then subcontracts with the Indonesian partner for part of the work, putting the Indonesian in a subordinate position on the research team. This is not necessarily acceptable to all donors, and the Indonesian may lose an opportunity to participate.

RECOMMENDATION 3

Eliminate the distinction between research and administrative career paths, and make the salary and benefits the same for both.

At present, scientists and engineers in government agencies must choose early in their careers whether they wish to follow an administrative path or a research career path. Even those who have received specialized training in science or engineering will hesitate before choosing a path that has less lucrative salaries and positions, and such a choice brings their dedication to their families in conflict with their scientific interests. The terms of the research career should encourage the best researchers to select a career that uses their skills fully.

RECOMMENDATION 4

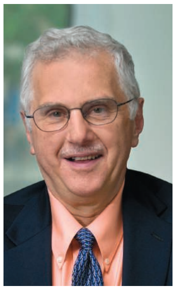
Allow the ISF grantee institution, whether university or LPNK, to receive overhead payments to support the indirect costs of research without subtracting the amounts from existing revenues.

The granting of research awards to an institution has economic consequences for the recipient. Research requires the support of administrative staff for accounting services, purchase and maintenance of equipment, and care of laboratories. There will be an increased demand for energy, water, and space. In some cases, the teaching staff may have to be supplemented, and the researcher will request salary to cover research time.

It would be counterproductive for the IFS to force the host institutions to pay for costs that are an inevitable result of the research project. Equally negative would be the effect of putting financial pressure on administrative staff, deans or directors, rather than providing incentives for them to encourage their researchers to apply for grants. The wealthiest and most prestigious universities and research institutions in the world are those that receive the largest amounts of grant funds, and part of the reason is that they are permitted to recover the legitimate indirect costs of hosting research grants, and consequently encourage their staff to apply for grants so they may profit from other benefits of a dynamic research program.

Appendix A
Editorial in Science by Bruce Alberts

EDITORIAL



Bruce Albert is Editor-in-Chief of *Science*.

The New Egypt

I HAVE JUST RETURNED FROM EGYPT, WHERE I ATTENDED THE ANNUAL BOARD MEETING of the Library of Alexandria and met with students and faculty at The American University in Cairo. This is a very exciting time to be in Egypt, with its people empowered by the success of their daring, peaceful demonstrations in Tahrir Square. But the exhilarating sense of freedom is combined with the tension of knowing that the revolution is still in progress and its end point not yet known. Clearly, a great deal of hard work will be needed to establish an effective democracy. In media interviews, I was repeatedly asked, "What should the role of science be in the new Egypt?"

Science is a globally generated, ever-increasing base of sophisticated knowledge about the natural world that greatly benefits humanity. The benefits include labor-saving devices, improved health and nutrition, and many other advances that increase a nation's prosperity and keep its voters satisfied. But only nations with strong, science-based institutions can effectively harvest this invaluable global source of knowledge, extending and adapting it to meet national needs. Democracies also require the creativity, rationality, openness, tolerance, and respect for evidence and logic that are inherent to science. The prime minister of India, Jawaharlal Nehru, recognized this 60 years ago when he called for a "scientific temper" for his newly independent nation, and a scientific temper is critical to every thriving democracy.

But as my visit made clear, a third aspect of science holds a special relevance for the new Egypt. Scientists in general take it for granted that, to be successful, the scientific enterprise must operate as a meritocracy. Ideas, results, and opinions must be evaluated independently of their sources, because it is what is said that is important, not who says it. Fitting with the democratic spirit of the Egyptian revolution, the scientific results of a young scientist are inherently no less deserving of respect than those of a senior Nobel Prize winner. For a nation to excel in science, college faculty, university leaders, and those who receive funding for research projects must be selected through competitive mechanisms that are entirely based on merit. Likewise, it is the establishment of a strong merit-based culture in both the public and the private sectors that will make the new Egypt successful.

There are lessons to be learned from the mistakes made by other nations. For example, years ago I was shocked by the remarks made by a scientific leader in India who, when asked about the major problem in his large research institute, told me that it was "getting people to work." In that conversation, I discovered that in India's government institutions, life tenure in one's position is normally granted after 1 year of work. This has also been the case in Egypt, and it has contributed to the widely recognized nonperformance of the Egyptian government. I do not believe that it is possible to create an outstanding organization—be it a division of government or a university—with such demoralizing rules. Clearly, an institution thrives when its individuals are not only held accountable for their work, but also when each person is judged by his or her merits, without respect to the individual's social status or personal connections.

But here is the problem. Who judges the merit, deciding which employees should be promoted and who removed? In science, unbiased peer review provides the foundation on which merit is decided. A similar type of peer review is generally used throughout higher education systems in the United States to produce excellence. But my nation is in the midst of a vigorous debate about how to shift to a more merit-based system for rewarding the 3 million teachers in our public school systems, where a lack of trust in leadership has long prevailed. For the new Egypt, as for the United States, finding a way to ensure that all institutions are merit-based will be a difficult, but absolutely critical, task.

– Bruce Alberts

10.1126/science.1207296

Appendix B
Indonesian Science Fund: Estimated Costs

The Indonesian Science Fund should be an autonomous institution under an independent non-government entitywith a government mandate, like AIPI, which is exempt from government budgetary and personnel regulations that hamper research funding, as is explained above.

There will be eight basic divisions, such as physics, chemistry, biology, engineering, agriculture, medicine, energy and environment, and social science and education. Each would cover specialized and applied topics within that field, like marine biology, microbiology, and biotechnology within biology. Biologyalso might include some basic topics related to medicine and agriculture, leaving the divisions for those fields able to concentrate on laboratory, field and clinical trials. We propose an initial research budget of 360 billion rupiah per year. This figure will comprise around 250 new three-year grants, averaging 500 million rupiah per year. That is an average of about 32 grants per division per year, although the amounts may not be allocated equally. Because it is uncertain at this stage what the needs of the new grantees will be in terms of equipment and replacement salary for classroom teaching duties, there should be flexibility in adjusting the factors of grant number and amount to apportion the budget for each division.

The cost of administration is estimated to be about 20 per cent of the total cost, administration plus grants. A large international grant program operated by the U.S. National Academy of Sciences in the 1980s (Greene, 1991) required 20%, and many other similar organizations require amounts in the range of 15 to 20 per cent. Once the Fund reaches operational capacity, this figure should be audited and may be changed. Meanwhile it would be unfortunate to underfund the start-up, especially when one-time tasks like writing of the bylaws and operational procedures are being addressed.

The total annual budget is estimated to be the proposedresearch grant budget of 360 billion rupiah, plus 20% of the total, or 450 billion rupiah (US$ 48 million).

The major elements of the budget are as follows:

1. Lease or rental of space. The space would accommodate eight program managers in private offices with a computer and telephone, a conference room for 20 persons, and an executive suite that could house the administrative staff, as well as director and deputy director.

2. Personnel
   a. Director. A senior PhD-level scholar with research experience, including international publications and grants.

b. Deputy director. PhD-level researcher familiar with science funding in Indonesia and with experience as a principal investigator of a research grant. The office of the deputy director will route all incoming proposals to the appropriate division for review.
c. Chief financial officer with training and knowledge of research project funding and accounting.
d. Deputy financial officer with auditing experience.
e. Eight division directors, with expertise in the area of responsibility of the division. PhD and research experience, preferably both within Indonesia and abroad, documented with publications, is required.
f. Program associates for each of the eight divisions with science training in the area of the division preferred. Some of these may be recruited for two-year terms from universities or LPNDs.
g. Executive assistants to director and deputy director.
h. Secretarial staff for each division.
i. IT staff to prepare website and online procedures for grant making and to maintain network.
j. Custodial staff, etc., as needed.
k. Drivers as required.
l. Honorarium payments for proposal reviewers and members of the Indonesian Science Board.

3. Equipment
    a. Computers, printers and server for all technical staff.
    b. Telephone system
    c. Vehicles for director and deputy director, at service of program managers.

4. Travel
    a. Review committees to Jakarta. Twelve persons, three days, four trips per year for each program where required.
    b. Program staff to visit 20 projects per year, two days, either routinely or for cause.
    c. Initial series of workshops to inform deans and laboratory directors of ISF grants. Two or more people from each research university and LPNK. Announcements by email and bulletin board posters to scientists and students.

5. Insurance

    In many countries, granting agencies and their employees may share the legal responsibility for errors or malfeasance committed by grantees. Unless the ISF falls under the protection or exemption of AIPI or the government, it will be necessary to secure insurance.

6. Grants

    The initial target should be 250 grants for up to 3 years, averaging Rp. $500 million per year, including overhead, for a total of Rp 375 billion. This budget figure will allow purchase of needed equipment for new grants, permit training of staff and students, and travel to initiate cooperation and exchange of information with other research groups, both in Indonesia and abroad. This number of grants is within the capability of a new organization and a relatively small number of candidate grantees, that is, PhD-level scientists who have active research programs and are not already fully supported by other organizations. If, in any year, many proposals are for less than 3 years, or if budgets are smaller, more grants may be given. For grants renewed in later years, with equipment already purchased, grants may become smaller, leaving more funds available to increase the numbers of grantees. The number of grantees working at any time within this budget figure could possibly exceed 1,000, but, eventually, for a country the size of Indonesia, the budget should be raised.

If possible, it is advisable that no grant be awarded without the full multi-year funding in the possession of ISF. A temporary or permanent change in subsequent funding level that may result in some grantees not receiving the full approved amount can be highly disruptive and cause loss of respect for ISF, as well as the dilemma of choosing between shortchanging existing grants and awarding new ones.

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