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Science in a Changing World

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Excellence in science and technology is surely vital to global economic and political influence. Most countries now understand and accept that science furthers technological progress at home and their nation's prestige abroad. With the growth of hypothesis-driven science in the centuries following the Renaissance, Europe quite simply came to dominate the world during the Industrial Revolution. Conversely India and China, amongst the richest nations in the world till the 18th century, became nearly the poorest, because they failed to recognize the importance of the scientific approach.

Quality and Quantity

Success in science is measured in terms of quality and quantity of research output, and how effectively this output is absorbed by industry, translating in turn to new technologies. It is very difficult to improve and sustain both quality and quantity simultaneously, especially in poorer countries and in countries without strong scientific roots and traditions. In larger and wealthier nations, scientific output appears to correlate with economic well-being. Surprisingly, an increase in quantity does not seem to impair quality. Rather, the converse appears to be true. Research papers from the U.S., China, and India during 1950–2010 serve as an example. These three countries represent three distinct stages of economic advancement. The U.S. has a very large research output but it is growing relatively slowly. China's output is not as voluminous but it is growing at a tremendous pace. The number of papers from India is not large and the rate of increase is also modest—the country is still poised for a take-off. However for all three countries, as the total numbers of papers increase, the numbers of papers in high-impact journals like *Angewandte Chemie* also increase by a comparable factor. The message is quite clear—quality is linked to quantity, and an increase in the numbers of papers also results in a concomitant increase in the numbers of good papers. So any move that is made by a country to increase the number of its research papers is, strategically speaking, a good move. This includes increasing the expenditure on research, starting new institutions, hiring more researchers and teachers be they local or foreign, and increasing the student enrolment, including foreign students.

Is there just one way of doing good science?

Single-Model Problems

If innovation, novelty, and cutting-edge science are what is needed, there is no substitute for a large research university with many faculty who are supported at relatively modest levels in single-investigator projects. It may seem archaic to extol the virtues of the research university, especially when several Asian countries are aiming for niche "wannabe" Nobel-oriented institutes, but ultimately teaching and research do go hand in hand. Teaching without research resembles a pond of stagnant water. The water stands stale and contaminated. Research without teaching is a mirage. We can only imagine the water in the pool.

A progressive society needs perhaps one good research university for every million people. But is it realistically possible to set up the huge number of universities that would be required to cater to the vast crowds of aspiring students in Asia? Such an enterprise would cost too much and it would take too long. The U.S. educational model of the 1950s and 1960s reflected the postwar prosperity of that country and its unchallenged control of all the economic levers of the world. Such a model could only be possible in a homogeneously planned country like the U.S. Asia, on the other hand, is much more diverse and has been too poor for too long. There is impatience in the air, and Asian countries, be they China, India, Korea, or Singapore will stop at nothing to advance quickly in the world of science. As the Asian economy surges, we will see more science and more good science emerging from this continent. But Asian nations may not be able to afford a single model like the U.S. research university. They need to adopt the trickle-down model from elite universities, the trickle-up model by energizing the vast numbers of children of school-going age, and any other kind of lateral trickling between universities, institutes, government laboratories, and industry. The large populations of these Asian countries are now seen as a distinct advantage, especially in India where almost half the population of 1.2 billion is below 25 years of age. In such a

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milieu, it is possible to "lose cheap". Simply increasing the outreach of science to teenagers in very ordinary ways may well be all that will be necessary.

Asian Dichotomy

Science and the economy are related and yet, the connection between education and wealth generation is troubling. Most U.S. actions and philosophies, and these include its education and research system, focus on wealth generation. In Asia by contrast, the traditional purpose of education has been to obtain knowledge and, ultimately, wisdom. Traditional medicine systems in Asia, for example, attempt a holistic healing of the body rather than cure specific symptoms. It is believed in India that the Goddess of Wealth and the Goddess of Learning do not visit the same home. There is then a strange dichotomy in Asia—we urgently need education to gain a livelihood and yet still seem to retain the feeling that the purpose of education is deeper. Education should bestow humility, rectitude, gentleness, and a sense of balance that the pursuit of Mammon defeats. Gandhi defined education as "an all-round drawing out of the best in child and man in body, mind, and spirit".

This Asian dichotomy will, one feels, linger for a while. India and China still look upon wealth somewhat differently from the U.S. Given that these two countries were the richest in the world till 1800, wealth is taken somewhat lightly—at a higher plane. In practice however, there is a feeling of urgency about the two lost centuries and a deep anxiety about being misunderstood by the rest of the world. So Indians and Chinese will do all they can to get rich quickly, even if it means that they abandon their traditional approaches. In the context of science, I think they will distance themselves from the limitless and inexorable rigor that is a characteristic of orthodox, reductionist science, take shortcuts and adopt intermediate technologies, and justify all this in attempting to balance excellence with timeliness. I suspect that education and research in large parts of Asia will be completely subsumed to the goal of wealth generation in the immediate future. But after Asian countries become moderately rich in say 25 years from now, I predict that they will revert to their ancient way of thinking, taking an integrated and more inclusive view of the world. Such a development need not be surprising—Asia is a very old continent and a few hundred years here and there are easily absorbed. But when large countries do change, there is unrest and tumult everywhere. The world of science had better be prepared for new and hitherto unseen situations.

Challenges

The major challenge in China and India is diversification of research effort, and the educational systems in these countries will have to take this into account. As for chemistry, this is a subject where many fundamental discoveries originated from an impulse within industry. But chemical industries in large parts of Asia are just not diverse enough; they are still unable to pose fundamental problems to academic researchers and have remained mired in copycat technologies, seemingly content with being a source of cheap labor. Production of synthetic intermediates in China and generic drugs in India cannot in themselves kick-start innovations in these countries. We do not see the academia–industry synergy or entrepreneurial activity that symbolized the U.S. economic powerhouse of the 20th century.

Asia easily absorbs a few hundred years here or there

While Asian countries are increasing their spending on science and technology, training more engineers and scientists, applying for more patents, and churning out more papers, the actual system for generating and realizing useful ideas in Asia remains quite underdeveloped. More scientists are indeed being trained, but this does not mean that they are doing good science. In the angst to revive themselves, these countries are falling into the trap of overbuilding; this is especially the case in China. Plagiarism and fraud are rampant. Asians are also unable to transform a stifling bureaucratic mindset that defers to age and seniority. Rote learning is the norm in China, India, and Japan, and in such cultures, those who don't match stereotypes are labeled as "too independent". As long as the U.S. maintains an open environment that moves ideas easily from the laboratory into the marketplace, and continues with its flexible immigration policies, it will continue to have an advantage over Asia. In terms of converting research ideas into saleable technologies and products, India and China still have a long way to go. They should start thinking in terms of not just cooperating with the U.S. but also competing with it.

Meanwhile, the Islamic world is in turmoil today with popular movements that demand greater inclusion, democracy, and intellectual freedom. Academics and university-trained professionals are spearheading this change in Arab countries, even as there is sustained discourse on the relevance and importance of science. Is there indeed something called "Islamic" science? Whether universities and research institutions that closely resemble the U.S. pattern can maintain themselves here in the long term still begs an answer. Countries like Singapore and Korea are experimenting with yet other models of education and research that depend in part on expatriate scientists. These approaches may work as these countries are small and affluent.

Vive la Difference

Science is international, its goals always remaining the same. The point to consider is whether the most effective ways to achieve these goals are different in different countries and cultures. Indians are best at being Indians, Chinese at being Chinese, and Japanese at being Japanese. All of us are best at being ourselves. Our disparities may be more than what we seek to disguise. They may even work to our advantage. Even as we remain mesmerized by globalization, these differences may be what we must secure as we aim for excellence and success in science education and research.