PHREE Background Paper Series

Document No. PHREE/92/71

Some Reflections on Science in the Low-Income Economies

by

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December 1992

Preface

Roald Hoffmann was born in Poland in 1937 and spent most of the first twelve years of his life in refugee camps or in hiding, until his family emigrated to the US in 1949. He did most of his graduate studies in chemistry at Harvard but spent one year as an exchange student in Moscow, USSR. After receiving his Ph.D. in 1962 he concentrated on the field of applied theoretical organic chemistry, and derived in 1965, together with R. B. Woodward, quantum mechanical rules for chemical reactions. These rules are today known by most undergraduate chemistry students. In 1981, Roald Hoffmann's work on chemical reactions was rewarded with the Nobel Prize in Chemistry, which he shared with K. Fukui from Japan.

For many years, Roald Hoffmann has taken a strong interest in the interphase of science with other fields, particularly the arts. The role of science in developing countries is also an area that he has dealt with through his work and travels. In early 1992, the Bank's Science Group asked him to present his thoughts on the subject in a lecture which gathered the largest audience the Science Group so far has seen. In this paper, which covers the material presented in the lecture, Roald Hoffmann discusses the role of science in history and in different parts of the World, especially the Developing World. Based on his own experience, which is not as limited as he suggests, he proposes a number of initiatives which may help developing countries benefit from the immense development opportunities, that in our times are offered by science. Based on this survey, he deplores the minimal attention given to science by some international organizations, including the World Bank.

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by

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Several Worlds?

It is, in the end, as it was in the beginning, only one world. While it may useful, pragmatically, to partition this blue, green and beige globe into regions which share roughly common degrees of development, everything operates to defeat the significance of such groupings. First, there is the uniqueness of the human condition. The vagaries of evolution produce a people (usually peoples, contending for the same small piece of tillable land), a language (dialects dividing them), a culture (cultures). Beer and bargaining are there around the world, but the local brew tastes different, and the way I buy a rug is surrounded by a different protocol of niceties with the dealer in the markets of Jerusalem, Moscow and Montevideo. Every "third-world" country is different: the way things don't work in it, and the way things do, are distinct.

At the same time, the very success of modern technology operates to defeat the assignment of distinguishing features to economic systems or to countries of vastly different gross national products. The air is filled with the same electromagnetic radiation. The high standards and low problems of the affluent societies penetrate via radio and television, via print, into the most isolated crannies of the poorer countries. It is possible for an unscrupulous American company to sell for a while a contaminated fertilizer in country Y, but it is impossible to keep the concerns of a European community about antibiotics or growth factors in animal husbandry from reaching the ears of the people of Y who are in charge of agriculture, and who have often been educated in Europe.

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*The material in this paper was presented, in somewhat different form, in a lecture at the World Bank. I am grateful to Dale Corson and Dotsevi Sogah for their comments on this work, and especially to Erik Thulstrup for encouraging me to think about this material.

So, diverse in the extreme, fated by the workings of evolution to be such, the world is uniquely many. And it is one. Which is no excuse for immobility in the face of natural or man-made disasters, of great suffering and a growing economic gap between people.

Science

What is the role of science in this world? Science is a Western European social invention. Together with technology, it has transformed this world. Science is a remarkably successful system for acquiring reliable knowledge (not truth, which has an ethical connotation), for harnessing the mental and physical energies of fallible individuals to understand and change part--not all, only part--of our condition.

Scientific invention, be it the wheel and the making of aspirin, is transplantable anywhere. But its origins are European. Technologies and protochemistries developed everywhere where human beings dealt with survival and aspired to comfort. The achievements of Chinese chemists and the metalsmiths of Benin or the Andes, the skills of Mediterranean dyers, were great. But science as such evolved in 1500-1800 in Europe, and nowhere else. Chinese chemists had incredible successes in the formulation of inks, in metallurgy, and native medicine, but in the end Chinese chemistry could not free itself from its alchemical steering force.

It took the fluid economies of Europe, enriched by colonialism, the contentious ethic of striving religions, the scholarly revival of classical knowledge, the beginnings of social mobility, and the invention of movable type to put into place, ever so slowly, a way of knowing that became science.

In our times, some popularizers of science (authors of books such as "The Tao of Physics") have claimed that there are other ways of knowing, and that science is halfway to Eastern philosophy. While I concur with the first part of this claim, that science is only one culturally-bound way to <u>know</u> this world, I think the second part is just an affectation, arising from wishful thinking and a confusion of the whole of science with the occasionally esoteric philosophical consequences of one particular field, theoretical physics. Every talented Oriental scientist I know, even those steeped in their own philosophical traditions, when he or she has practiced science successfully, has practiced it in the Western mode.

There have been legitimate critics of science from the feminist side, pointing out to us the aggressive, male nature of the enterprise. The 19th century banner phrase describing our supposed aim, "to unveil the secrets of nature", is revealing. One may think (I actually do so) that the way of doing science should change, that supposedly female traits of cooperativeness, of sensitivity to the environment, should enter the ideology of science. But there is no taking away that what has worked, no more or less male-dominated than any other part of society, is traditional European science.

It has been argued (see for instance Sagasti, 1980, 1983) that the future of the world must involve an "advance towards a 'third civilization' in which the achievements of modern science could be integrated in a harmonious fashion with the cultural heritage of non-Western societies." I vacillate between an idealism that concurs with this outlook (and seeks to implement it, see below) and a realism, based on historical precedent, for the inability of ideals to stand up to technological pressures.

The Democratizing Nature of Chemistry

Science and technology do function. They have transformed this world, mostly for the good. With some ill consequences. While supposedly ethically neutral, the effects of science are inevitably democratizing.

The world that my great-grandparents were born into 150 years ago in the Austro-Hungarian province of Galicia, the world of the backwaters of Zaire today, was not a romantic paradise. It was, and for so many today it remains, a brutish, inimical environment. Perhaps one lived in balance with it, but with a life span far from biblical. One only has to look at the cemeteries of the last century, or read the heart-breaking diaries of our ancestors, to see the tragedy of seven children out of eleven dead before puberty, of child-birth a killing prospect. When I hear an opponent of technology speak against modern, chemically-intensive agriculture or pharmaceutical therapy, my heart beats quicker in a rush of anger at the implicit lack of simple human sympathy in his or her stance.

A doubling of our life span, less death and suffering, a greater color palette to lift the spirit, freedom from the smell of sewage, a way to cure much, not nearly all, disease; air, light, food for all; food for the soul in the Ramayana on the screen or a Mozart rondo in the air--these are things of which scientists and engineers really can be proud.

Technology and science also serve the evil side of man, as the elements of subjugation, propaganda and even torture. Some would see in this the ethical neutrality of science, and even a reason to condemn it. Quite aside from the misuses of science, to many in the low-income economies science may appear as a luxury of the elite, or just another element by which the privileged classes hold down poor people.[1] But I really do think that the overall effect of science is inexorably democratizing, in the deepest sense of the word--making available to a wider range of people the necessities and comforts that in a previous age were reserved for a privileged elite.

Chemical Industry

Here is a chart of the top ten hits of the chemical world (Table 1). These are the chemicals produced in greatest amounts in the US in 1991 (Chemical and Engineering News, 1991)

Table 1: The Top Ten Chemicals, by the Amount Produced in USA in 1990

	Chemical	Amount Produced (billions of lb)
1.	Sulfuric acid	88.6
2.	Nitrogen	57.3
3.	Oxygen	39.0
4.	Ethylene	37.5
5.	Lime	34.8
6.	Ammonia	33.9
7.	Phosphoric acid	24.4
8.	Sodium hydroxide	23.4
9.	Propylene	22.1
10.	Chlorine	21.9

Number 1, produced in perhaps 200 billion pounds world-wide, is sulfuric acid. Not on the shelves of your supermarket, it is intimately involved in almost every industrial

[1] I am grateful to Barbara Lynch for making this point to me.

chemical transformation. You can judge the GNP of any country by simply looking at the amount of sulfuric acid it produces.

The chemicals that you see on this list are the feedstocks, as they are called, of the "chemical and allied products industries". From these are made, quite directly, plastics and resins, synthetic rubber and fibers, drugs, soaps and detergents, cosmetics and toiletries, paints and varnishes, and fertilizers and pesticides.

But chemistry reaches further. It is the science of substances and their transformations, and is intimately involved in many other industries, those dealing with ferrous and nonferrous metals; petroleum; food; coal and coke; pulp and paper; stone, clay, and glass; and electronic equipment. Not to speak of military uses.

Environmental Concerns

There is no way of making such vast transformations of matter as the production figures of Table 1 represent, without occasional damage to individuals, property, and the environment. The production of sulfuric acid is extraordinarily safe and effective. Still the acid industry has accidents, and through its inevitable dependence on energy sources, it contributes to acid rain and CO_2 production.

Is this enterprise, addictive to its practitioners, economically successful (the true price of all materials keeps falling), democratizing, is it also a recipe for eventual destruction of humanity? Unable to control our procreative capacity, destined to exhaust the limited resources of this world, certain to perturb its global cycles, we seem to be headed for disaster. We must change, some would say, and that change needs to entail a limit to technology and unbridled progress, a caging of the genie that Europe released.

I don't think a brake on technological advance is feasible--I think change will come as it always does. Moreover, I refuse to conceive of limitations on human ingenuity. It's impossible for homo faber to suppress curiosity and the will to transform and make things. This is not to claim that the fix will be technological. Far from it. True change in the way we use transformation will come from a combination of economic and moral pressure. The will to repair that which has been made and, willingly or not, broken comes from the spirit (Hoffmann, 1991).

The Importance of Science to a Developing Country

Can a country attain a high-income economy without a scientific infrastructure, without a high level of average science education and a research structure? Discount the oil-rich Arab countries and the answer is a resounding "no". To transform nature one needs to know it, intimately. It is precisely this knowledge that science provides. A consistently high level of primary and secondary education, good universities, a research structure of one type or another (the French CNRS is very different from the USA university-driven research establishment) are necessary. Seventy percent of US Ph.D.'s in chemistry enter industry; the industrial demand for chemists prods the universities to maintain the research structure that both trains this work force and advances research.

Basic science and ingenious engineering combine to build the matter-transforming industries of this world. The new kids on the block in the chart of ten top chemicals, the molecules not on there 50 years ago, are ethylene and propylene. These are the building blocks of the synthetic polymer industry; more than half of all plastics and synthetic fibers originate from ethylene. Ours is the polymer century; synthetic polymers have passed iron and wood in volume produced. The commercially viable polymerization of ethylene is the consequence of fundamental scientific discoveries by Karl Ziegler in Germany and Giulio Natta in Italy.

A Strategy for Scientific Development

What I say here is inspired by the work of H. Harry Szmant, who has had much experience with chemical development in the Caribbean (Szmant 1984, 1987). The changes required are economic, political, and scientific, and nothing at all will happen (whether one is trying to move a country to a higher stage of development, or to solve the drug problem in the United States) unless there is a national will. This is not to be found in the mind of a dictator, but in the sometimes amorphous yet nonetheless real shaping of a general awareness that something must be done.

The "Induction" phase, as Szmant calls it, needs to contain an analysis of the national economy from a chemical viewpoint. This is not a self-serving proposition, I think, but a recognition of the centrality to any economy of transformation of matter. The Induction period should go on to the "...study [of] potential import substitution by materials that are either identical to those currently imported or by other materials that perform similar functions; and potential increases in exports by value-added transformations of traditional export materials..." (Szmant, 1984). A substantial investment in education, of a high standard at the primary and secondary levels, is critical.

A "Preparation" phase should follow, in which local expertise in specific technologies is demonstrated. Here protection against external technologies may be needed, and/or the provision of incentives for the local industries, even if they duplicate technologies that are imported. A hard-nosed economic evaluation of the fledgling technologies is required. And a continuing flow of resources into education, as well as the construction of incentives for foreign-trained professionals to return home.

Nothing is linear in the real world. The phases of reaching for development may proceed simultaneously, and will take form differently in each country. Yet unless these components of a strategy are present, the best intended aid and development efforts will go astray.

Can One Do State-of-the-Art Research in a Low-Income Economy?

Yes, I'm certain it can be done. Not all science is big science, and in fact my own science, chemistry, is most certainly small science. Credible, innovative research in chemistry can be done for actual outlays of around $10,000 per piece of publishable research (a measure I hate to use!), providing one has access to shared instruments costing under $200,000.

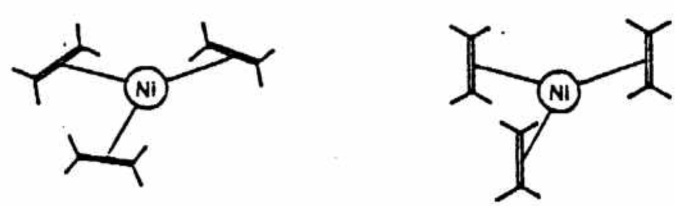
Not every subfield of chemistry is amenable to this cost scale of innovation. The studies of surfaces under high vacuum, femtosecond spectroscopy, and gene-sequencing are not. Natural products and polymer chemistry, approximate calculations on molecules (what I do) are. When students from a developing country are sent abroad for graduate study they will opt for the science-not-doable-at-home as often as they will for the feasible. One longs for some paternalistic direction here, or at least a sensitivity by the students' research advisors to their future. There is nothing sadder than a young researcher, brilliant in graduate study, returning home but unable to display his or her talents. Or psychologically incapable of adjusting his or her research to his or her environment.

In his recent autobiography (Djerassi, 1991), Carl Djerassi describes how he and a group of talented coworkers "placed Mexico on the map of steroid research" in the forties and early fifties. This is not an exaggeration, nor a unique instance. The flora and fauna of many developing lands (and their seas), their native medicines, are a rich, still largely unexplored source of potential therapeutic agents.

The Author's Small Experience

Now I have to pass from high ideas to the realities of science and development in this world. The sulfuric acid, so easy to make, is not made in quantity in Madagascar. The talented Russian chemists who soon will fill our American graduate schools are not likely to return home. The number of Ph.D's trained this year in ecology and systematics in Latin American, desperately needed to inventory the rain forest, can be counted on the fingers of two hands. Within the existing system of science, how can we deal with the problems of developing countries?

My expertise in this area is minimal, which is typical for research scientists in the highly industrialized countries. I search for the factors determining the shape, on the microscopic level, of those tiny chemical entities, molecules, and the factors governing their reactions (why carbon monoxide binds better to hemoglobin than oxygen, why three ethylenes around a nickel lie down, rather than stand up as soldiers, as shown below).



This, our business, is addictive. Totally consuming, science swallows up all our time. The toys we play with, hundred-thousand-dollar vacuum chambers, esoteric spectroscopies, computers, are the stuff of the developed world. There seems to be too little time to think of the problems of the rest of the world.

My own intellectual world has been perturbed, however, by the occasional encounter with scientists from developing countries, by a small degree of social concern, and by my abiding interest in the art and literature of other cultures. These perturbations have been essential to me. And since they form the basis of whatever little I know of the world of low-income economies, let me recount these contact points:

1. In 1960-61, as a graduate student, I spent a year on an exchange in the Soviet Union. The stay was instructive in putting a mental brake on my naive socialism, typical of intellectuals. But it also left me with a strong interest in Russian culture, and with an appreciation of the strength of the innate drive for knowledge, persistently pursued under difficult, to put it mildly, political and economic conditions. I came back often, to help keep the window on the world open for my friends. And for me.

2. From that year in Russia I acquired an interest in the ways communism overlaid, ever so thinly, the cultures it has governed. This pulled me, I think, to look at the People's Republic of China. Another pull has come from the masses of talented young people, just eating up science, who have come from this vast land. And, moved in part by interests in Latin American culture, I've built a set of collaborations with Cuba. The people trying to work in Cuba have impressed me, and so, despite useless barriers put up by our own government and the inefficiency of their system, we have managed to exchange people and computer programs.

3. At a Congress on Chemical Education in Canada, I saw a poster by a chemist from Botswana. He described a set of classroom experiments, determining the kinds of long chain fat molecules (there are several, differing in the number of carbon atoms) in the common cooking oils of Botswana. I was impressed by the combination of science and applicability. This was appropriate chemistry. I remembered a talk I gave the previous year at the opening of a laboratory for Henkel, a major German oleochemical producer. Henkel uses vegetable and animal oils as raw materials. I put the Botswana scientist and Henkel in touch with each other. And later I helped, just a little, in raising funds for an African congress in Chemistry. From contacts with two other African scientists, one a sabbatical visitor to Cornell, the other an outstanding younger colleague of mine, I have formed a dream, of bringing more African chemists for training at Cornell.

In Lund, Sweden, where I was on sabbatical five years ago, a Nigerian student in my class and I spoke Russian. He had received part of his graduate training in the Soviet Union, a consequence of modern geopolitics. That student and a coworker of mine have since written a nice paper on the way a vanadium oxide catalyst works.

4. My interest in a country often begins with its literature. So Donald Keene at Columbia taught me Japanese literature, and Japan has remained a focus of my artistic interests. In another cultural context I read Borges, Garcia Marquez and Fuentes. And went on to Adolfo Bioy Casares, Clarice Lispector, Carlos Drummond de Andrade, Heberto Padilla and Guillermo Cabrera Infante. The literature of South and Central America, and its music, has shaped my image of these countries. The reality, be it the sad state of university education in Uruguay or being mugged in Rio de Janeiro, has not discouraged me--I've built up collaborations with groups in Uruguay, Brazil, Mexico and Cuba.

What Is to Be Done

From these collaborations I've learned a little about the difficulties of life and doing science in low-income economies. And I've learned something about myself. I do not have any special wisdom as to what needs to be done, and much less on-the-job knowledge. But let me throw out for consideration some suggestions, which do grow out of personal experience.

1. Sensitization visits. The most productive interactions are those founded on personal involvement. A university teaching laboratory in Bangladesh will be equipped properly if a Swedish teacher works on site with a Bangladesh professor on ordering the material. It takes so little to establish contact; just a few days in the life of a busy scientist can transform his or her life, sensitize one to the desperate needs and achievements of a colleague in a developing country. Long term visits such as those of the Fulbright Program and the Peace Corps, the main contact points of US academics with low-income economies, are fine. But how many more who could help would be reached by a program of short term, a week to two, trips. The visible plight of the third world has a way of transmuting a junket into a committed collaboration.

2. Teaching Appropriate Science. Sylvia Ware has written for the World Bank a perceptive, well-reasoned report on secondary school education in developing countries (Ware, 1991). One of the points she makes, and with this I strongly agree, is that science curricula, especially at the lower levels, need to bond to the nature and culture of their societies. This can be done--witness the Botswana chemist's cooking oil analysis.

Natural history is, in my mind, the ideal way into science. Observation and experimentation with local flora and fauna should be encouraged; also the mix of modern technique (a chromatograph to separate the components of a medicinal plant) and old ways of knowing (the efficacy of that plant in native medicine) creates a tie between the two worlds in which people in developing countries must move.

Hamid A. Dirar, a Sudanese microbiologist, has been documenting the incredible range of fermented foods in the Sudan. Not only do milk, meat, fish and grain serve as substrates but bones, hides, gall bladders, fat, locusts and frogs are fermented as well (Dirar, 1992). The exploration of the methods (older women are the repositories of the lore) and the organisms at work in each case (modern microbiology, but not too complex) is important and instructive, a valuable scientific investigation in consonance with the culture.

3. Education stressing science. One can't build a developed, high-income society, or even one somewhere near the middle, without an educated population, and specifically one numerically and technologically literate. World Bank and IMF loans justifiably concentrate on infrastructure--roads, airports, health, communication. And education. I'd just like to see a little more emphasis on science.

My Cornell colleague Dotsevi Sogah remembers his high school years in Kwame Nkrumah's Ghana as a period of emphasis on science. At all grade levels science study was compulsory. At the university there were special allowances (additional stipends) for science students. An accelerated admission system to the university was worked out for the best students. Whatever the failings of Nkrumah's regime, the stress on science worked. We see many Ghanaian scientists around Africa.

4. Science-connected entrepreneurial activity. Personal gain is an unparalleled spur to physical and mental activity, and, as Adam Smith argued, not inconsistent with the general good. Small scale business activity could be encouraged at the university level. Here are some examples:

(i) Most chemical transformations are really simple--be they the production of soap or heroin. Yet many low-income economies import, needlessly, simple chemicals. I would propose a survey of chemical imports in each country, a classification of these by a group of chemists and engineers, singling out those that can be synthesized easily with locally available starting products, and a set of small incentives (loans) to individuals or companies to do just that. I know such a project in Cuba on pesticides.

(ii) At an even lower educational level, students could be organized to provide inventories of species or trained to collect organisms or plants needed for some specific scientific activity.

(iii) Universities should be encouraged to set up production facilities for instruments, common and complex, used in science. There is substantial activity of this kind in the People's Republic of China.

5. Experts who share a language. This is a point made to me by Dale Corson on the basis of his Ford Foundation experience in Latin America. US instructors could not establish the rapport and informality needed for effective teaching; Mexican experts, sharing a culture and language, did much better.

The experience of others who have struggled to build science in similar cultures is invaluable.

6. Using emigres as a bridge. Scientists from developing countries who live in high-income economies, whatever their citizenship, are a valuable human resource. They remain culturally tied to their country of origin and cognizant of problems of development "back home". And they may harbor a strong sense of responsibility to the people left behind. That sentiment, shading to guilt, should be used--by their countries of origin and sponsoring agencies. Such emigres, easily identified and organized, might serve on panels negotiating aid agreements on behalf of their country. Resources made available specifically to them are likely to be used most effectively because they usually know best who is doing good research back home.[2]

7. Windows on the world. Feeling part of the world of science is essential to creative activity. The cost of journals and monographs is such that few developing countries can afford an even minimal collection. The vaunted openness of scientific communication is meaningless to the chemist who can't purchase a journal. While the World Bank can't restrain the rapacity of journal publishers, perhaps it could gain a negotiating position by buying a substantial number of subscriptions and bargaining for reproduction rights.

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[2] I am aware that there sometimes are political reasons for emigration, and insuperable political barriers separating people from one and the same country. These may well prevent implementation of this scheme.

Access to the literature is now much easier through data bases and computer searches. The placement of computers to access such remote sources of knowledge at just one university or national library per country would be a high-leverage investment.

8. Scientists meeting together. Free interchange of the new is part of what makes science so exciting. We have mastered the ethic of collaboration, with which the arts and humanities have some trouble. Especially important are regional international meetings in the developing countries, for there local scientists are not intimidated by the high technology of their colleagues. I was amazed to find that the World Bank did not have a mechanism for support of such conferences.

9. A consulting company for hire. Developing countries are often faced by proposals from potential investors in high-income countries for development of this and that resource. They need advice, both scientific and economic, on how to respond. Advisors are often hired, at great expense, in these situations. But I suspect that the advisors often have their own agenda. What if IMF or the World Bank set up a consulting company, with a staff of scientists, economists and managers, with the advice of resident emigrees, who could respond quickly and at low cost, to requests for advice?

10. A minicourse blending science and economics. Often the individual academic disciplines (chemistry, economics) are well taught in institutions of higher learning in the low-income economies. But their interface to reality is missing. I have in mind a traveling, intensive course that:

(1) teaches the current industrial processes for transforming matter;

(2) analyzes the economic factors that affect the supply and demand for raw materials and finished, transformed products;

(3) gives people the ability to identify the chemical imports on which a developing country is dependent; and

(4) does this by case studies, stressing entrepreneurial activity.

A team of academic and industrial chemists could teach such a course; the subject matter discussed is normally scattered in chemical engineering, economics and business school courses and rarely brought together.

11. The World Bank, IMF and their contracts. Money and good business practice are the blood and muscle of development. So it is no wonder that the management of these institutions and the teams that negotiate World Bank and IMF loans are dominated by

economists and business people. But the industries that are built as a consequence make cement, steel, pharmaceutical, fertilizers. These are technologies, based on science.

It makes sense to have scientists and engineers along in the decision making process. The boards of directors of most non-chemical companies have scientists on them. Not to speak of the duPonts, Hoechsts and ICIs of this world. The World Bank and IMF need sound technical advice in their management structure. Why do I see so few scientists there?

These influential organizations should require that every negotiating team from a client country contain a scientist from that country. Emigrants resident here or in Europe could play an important role in this process, a point made to me by Dotsevi Sogah.

12. Getting students to return from abroad. This is the highly sensitive "brain-drain" issue. As an immigrant to the US, I am torn--I would like the door open. I would like individual decisions on immigration, be they economically motivated or not, respected. And yet I grieve for what is lost when the superbly trained foreign students do not return home.

Clearly "home" must be made more attractive, even if cultural ties are strong. I would suggest a program of research grants in hard currency, to be used in the country of origin, for people who obtained their Ph.D in a high-income economy and who return. In those grants should be a liberal travel allowance, and perhaps a sum to maintain and reinforce contact with the Ph.D. granting institution by sending a "grandchild", a student of the former student, there.

Science and Development

These suggestions may be judged unrealistic, or they may flog the obvious. Each requires resources, and these are limited. Here the World Bank and IMF are in an enviable position, for they control the purse strings on purses that to the developing countries are immense. These institutions command respect, and can guide significant change.[3]

Development in our time is inseparable from scientific advance. Without a corps of trained technicians and advanced scientists, without a scientifically literate work force (not that ours is a stellar model), low-income countries will remain forever just buyers and aid-recipients. They must be empowered to transform matter; to turn ores into metals, to make

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[3] There are some signs that The World Bank is responding to the major role it must play in science and technology development (see Sagasti, 1991).

polymers, to isolate the medicinal from an herb, and to modify it in the laboratory to make a new drug. Science alone will not guarantee a transition to an economy of adequate income. The infrastructure, a functioning market, democracy, a national will manifested through personal involvement are requisite. But it cannot be done, at least today there is no way to do it, without science.

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