is that of adaptation, of which the steady-state level is primarily set by the light flux. But, since adaptation is tested by a growth response, every "dark" process contributing to cell enlargement is also implicated. From these sources comes the prompt negative feedback after an increase in light flux, as well as the conservation of growth seen in bending. Use of light by the plant seems to be only for operation of a crude guidance system for spore dispersal. For the investigator, light is a tool that displaces or unsteadies the mechanisms of cell extension and gives glimpses of their otherwise-concealed complex interplay.

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The Brain Drain: A U.S. Dilemma

The nature and extent of the brain drain, its effects on welfare, and its implications are analyzed.

Herbert G. Grubel

The migration of highly skilled individuals from the rest of the world to the United States, often called "the brain drain," puts U.S. society and policy makers on the horns of a genuine dilemma: On the one hand the United States is morally and politically committed to assist the development of the poorer regions of the world, and anything retarding this process, such as the loss of high-level manpower resources through emigration, runs contrary to the declared foreign policy of the nation. On the other hand, the United States has considered it to be in its national interest to restrict general immigration and make it selective through a set of laws and regulations that favor individuals with high levels of training. Furthermore, the country has a tradition of respecting personal liberty, welcoming the poor and oppressed, and avoiding coercion, so that under certain circumstances students are permitted to become immigrants even though laws and visa regulations would otherwise require them to leave the United States after completion of their studies.

In recent years countries throughout the world have awakened to the brain drain, as is evidenced by frequent articles in the foreign and U.S. press (*1*); the authors expand and popularize whatever empirical evidence regarding the magnitude of the migratory flows has been assembled by international agencies, national governments, and scholars. The catchy phrase "brain drain" has penetrated the public consciousness, and its implications are frequently discussed among intellectuals. The U.S. Department of State in June 1966 held a conference during which government officials, representatives from private organizations, and scholars discussed the issues surrounding the brain drain. The United Nations, the Pan American Health Organization, and the Organization for Economic Cooperation and Development are preparing studies and conferences to assess the magnitude of the problem and to arrive at policy stands. Recently, Walter F. Mondale, U.S. Senator from Minnesota, spoke (*2*) of the problem on the Senate floor; he summarized the government's dilemma by quoting Assistant Secretary of State Charles Frankel:

> This is one of the steady, trying, troublesome diplomatic issues confronted by [our] government . . . one of the most important problems faced not just by the Department of State, but more important, by the United States and by mankind as a whole.

Before the United States can develop a program to deal with the complex phenomenon so conveniently labeled the brain drain, its nature and magnitude must be understood more clearly than hitherto.

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Nature and Magnitude

As most researchers in the social sciences have discovered, journalistic exploitations of individual episodes, or even concern by governments or international agencies, are a poor base from which to make projections of general validity. The brain drain is no exception, and efforts to examine more deeply the nature of the phenomenon and somehow quantify its magnitude unveil unexpected complexities and difficulties.

At the very outset, there arises the conceptual problem of which immigrants should be considered contributors to the drain. Most countries welcome general emigration of their citizens, since it relieves pressures on population and resources. An ordering of such general immigrants by the levels of their skills shows a continuum ranging from uneducated children to unskilled labor, skilled artisans, students at various levels of educational attainment, and professional (including scientific) holders of degrees—fresh out of universities or with many years of experience. Thus the question is where in practice does one draw a line between immigrants whose departure is welcomed by their native countries and those who are considered contributors to an undesirable drain. One study has arbitrarily chosen a university degree as a cutoff point in defining brain drainers (*3*).

Students present a special problem of measurement and definition. In most studies students are distinguished from immigrants by the type of visa under which they enter the United States, but many graduate students, postdoctoral fellows, and established professionals come to the United States with immigrants' visas even though they definitely plan to return home after their periods of training. These people tend to prefer immigrants' visas because thus they are permitted greater flexibility in choice of employment during their temporary stays. On the other hand, many visitors arrive on student visas with permanent immigration as their ultimate goal.

In one sense, definition of students by type of visa is irrelevant because, as far as their native countries are concerned, any young person leaving for study abroad is unskilled and relieves population pressures. At the same time, a student's studies abroad and his failure to return home do not mean that his native country's stock of *educated* people is reduced by one; rather that the stock of *uneducated* people is reduced, since the emigrant's vacant place in his country's educational system is taken by a person who otherwise would not have received the schooling. In the light of this fact, countries benefit from having their students in the United States, even though none return. In fact, however, the State Department estimates that only about 10 percent of foreign students remain permanently in the United States (*4*).

Many people argue, however, that the relevant distinction is not between having and not having U.S. study programs for foreigners, but between having these programs and ensuring that all students return home rather than become permanent immigrants. From this point of view, the student problem is logically analogous to the broader question of whether a country is better or worse off when some of its highly skilled citizens emigrate.

The answer to this broad question depends decisively on the definition of the country one chooses and what one considers to be the proper index of national well-being that a country's leaders should maximize. On the one hand, there is the concept of the nation as an aggregate of individuals living in a given geographical area. The index to be maximized is the nation's standing in the world community in terms of population, military power, national output, cultural achievements, and so on.

In recent years the world has seen a revival of the game in which countries try to maximize this index, a phenomenon known as the growth of nationalism.

There is no doubt that the emigration of skilled manpower is a loss in the eyes of nationalists. Perhaps the entire worldwide concern over the brain drain can ultimately be attributed to the revival of nationalism, and the United States will have to accept it as an unavoidable fact of life. However, while the United States is impotent to deal with the desire of other countries to seek nationalistic objectives, there is a real question as to whether U.S. policies should be designed to help countries to achieve such objectives. Nationalism, with all its costly manifestations of excessively large armies, inefficient show-case industries, and monuments, often reduces severely the income of the countries' populations, whose power-seeking leaders never give them a choice between higher levels of real income and consumption of more nationalism.

Instead, and in line with the second concept of a country, the United States has the option of designing policies to increase the welfare of people regardless of where they happen to reside, most importantly through helping them to a higher level of real income. Under this second concept, a country is a collection of individuals *born* in a certain geographic area, and the index to be maximized by national policies is per capita income. From this point of view, voluntary emigration increases the welfare of the total population if it makes the emigrants themselves better off—as it should do if they choose to migrate—and if the remaining people's incomes are not reduced.

Given this focus on the welfare effects of migration, the entire problem of understanding and measuring the magnitude of the brain-drain phenomenon takes on a different form and should center on the issue of whether or not the emigration of highly skilled people reduces the well-being of people remaining in the country of origin.

Effects on Nonemigrants

Economic theory establishes a very strong presumption that emigrants, brainy or not, do not affect the well-being of the remaining population. Individuals on the average are paid amounts equal to their contributions to the value of national output. This marginal-productivity theory of wages and interest, widely accepted as a basic hypothesis, implies that emigrants take along both their contributions to and claims on production, thus leaving the other incomes unchanged. Similarly, in terms of "free" government services, emigrants cease to claim them when they stop paying taxes. Even the fact that the emigrants may have been educated through public school systems does not affect the well-being of others, since education is most rationally viewed as a process whereby the currently productive generation provides resources for the education of its children. An emigrant does not pay his share of the cost of education, but neither does he contribute children to be educated.

Logically, arguments about losses in welfare in the relevant sense must be based on the following conditions:

First, there may be short-term losses resulting from inefficiencies when established, highly skilled persons leave functioning working groups without leadership; this factor is theoretically a significant possibility when truly outstanding persons are attracted to the United States. No data are available to document the frequency and magnitude of such losses, but one should remember that no person is irreplaceable in the literal sense, and that other countries have very effective nonmonetary methods of retaining their outstanding scientists and other professionals. At the same time, nonreturning students can safely be assumed not to cause losses of this kind, since they never were integrated in their native economies. However, case studies of losses in this category are needed badly.

Second, people must affect the well-being of others in ways for which the market does not reward them, so that their departure reduces output by more than they were being paid for. Nor is there documented evidence of the extent to which brainy migrants produce more than they are paid for, although this source of welfare effects on others is probably the most significant through such phenomena as "leadership," "entrepreneurship," and other elusive qualities of successful people.

One of the most important sources of welfare benefits for which persons are not rewarded individually is the field of research, especially basic research. But here the argument about losses of national welfare breaks down because knowledge produced by the emigrants in the United States becomes freely available to their native countries as soon as it is produced—and it does so at zero cost.

Third, the person emigrating is above average in his contribution to government revenues; this point is likely to be true if the migrant is highly skilled. But the validity of the complete argument that his departure reduces welfare depends on proof that he would not have also absorbed more than an average value of government services. There are strong indications that above-average taxpayers also use more roads and other services—as well as demand above-average education for their children—than do average taxpayers; and that only a relatively small margin of their taxes goes toward redistribution of income.

Fourth, the emigration of highly skilled people leads to more than just "marginal" changes in wages and output, so that the classical marginal-productivity theory of wages is invalid. This possibility is rather remote for the developed countries of western Europe. One study shows that during the period 1957–61 on the average 3150 scientists and engineers immigrated annually to the United States from 11 western European countries and Canada. For the European countries these losses averaged as much as 9.2 percent of the annual output of first-degree engineers and scientists (*5*). Unfortunately, similar statistics are not available for scientists from less-developed countries, but some fairly reliable evidence suggests that the annual immigration of non-Cuban doctors of medicine from Latin America is roughly 250 to 350—about 5 percent of the annual production by all Latin American medical schools outside Cuba (*6*).

While classical economic analysis presents a strong theoretical case for the proposition that welfare in the emigrants' native countries is not reduced, a good theoretical argument can be made that emigrants have some positive influence on their former countrymen's welfare. The empirically most significant case has already been mentioned, in which talented scientists and engineers add to the stock of human knowledge through their work in the United States. This knowledge then becomes available at zero cost to their native countries and represents a net addition to knowledge, since the costly research could not have been done outside the United States. Moreover, such people send home remittances, raising the disposable income of their relatives; they often give counsel to their home governments and in general retain an interest in the affairs of their native countries, spreading goodwill about them in their new habitat.

Researchers concerned with human migration and the brain drain have worked out these theoretical arguments about welfare losses in considerable detail without being able to quantify any of the empirically relevant measures that their theoretical considerations have shown to be important. In part this failure is due to the elusiveness of welfare effects in general, which tools of economic measurement have been unable to capture; the well-known lack of statistics on the nuisance value of industrial pollution is another example of this general failure to quantify effects on welfare.

Relevant Statistics

Available data and measurement techniques were nevertheless applied to the calculation of some statistics relevant to the brain drain. Unfortunately these statistics concentrate on the number and value of human migrants and educational services crossing international borders, thus expressing the importance of the drain from the nationalistic point of view and giving it greater play than it deserves according to the theoretical considerations.

With this fact firmly in mind, one is interested to note that, between 1949 and 1961, 43,523 "scientists and engineers" (as classified by the U.S. Immigration and Naturalization Service) entered the United States as immigrants. The human capital embodied in these persons (that is, the resources spent on instruction, plus the value of their output had they produced rather than studied from the age of 14) amounted to more than $1 billion; and they represented approximately 10 percent of first degrees awarded in the U.S. during the period. Very few of these scientists and engineers came from underdeveloped countries; most were born in or came from the major countries of western Europe or Canada (*7*).

Such flow data are not very reliable because many of these alleged immigrants ultimately return to their native countries. So that the net effect of past flows back and forth could be seen in perspective, the stocks of some U.S. professions were examined with respect to the national backgrounds of their members. For example, 12 percent of all U.S. economists are foreign-born; of these, 75 percent also have a foreign high school diploma, but only 25 percent have been fully educated abroad. On average, completely foreign-trained individuals are paid less than are their colleagues born and trained in the U.S., while economists having European or Canadian high school backgrounds plus U.S. professional training receive above-average salaries (all in comparable employment and age-brackets). Only 196, 31, and 18 U.S. economists were born in Asia, Africa, and South America, respectively; together they represent about 18 percent of all foreign born and 2 percent of the whole profession (*8*). Recent analyses of other scientific disciplines covered by the National Register of Scientific and Technical Person-

nel show that in physics, chemistry, biology, and similar fields individuals of foreign birth and foreign secondary education represent 7 percent of the total membership of these professions —a figure remarkably close to the 8 percent found for economists in the previously discussed independent study (*9*).

Other complicated calculations, using the human-capital concept and refined estimates of social costs of education, have led to the conclusion that on balance the world as a whole receives capital from the United States through exchange of foreign students, even with due consideration of the "value" of nonreturning students; thus in the year 1962–63 the 64,700 foreign students in the U.S. entailed a gross social cost of $148 million while the resources absorbed by 17,100 U.S. students abroad were valued at $30 million. The nonreturning students—10 percent on average (assumed)—charged against that accounting year represented human capital worth $72 million. After some additional adjustments, the calculations showed a net transfer of resources totaling $15 million from the United States to the rest of the world in 1962–63 (*10*).

Canadian politicians and newspapers are particularly vociferous about the brain drain to the United States. Surveys and calculations of the U.S. and Canadian economics profession show that on balance Canada has received U.S. resources in the exchange of training of individuals who in 1964 were active members of the profession in the two countries (*11*).

More empirical evidence regarding the magnitude of the brain-drain problem, both as a simple measure of international transfers of resources and, more importantly, as a source of welfare effects, needs to be produced. In addition, sociologists and psychologists are needed to study the personal characteristics of migrants, so that future U.S. policies can incorporate the most effective incentives for the achievement of policy objectives.

Basic Principles and Recommendations

The existing theoretical and empirical research, however, permits formulation of some basic principles and specific recommendations that should be incorporated in U.S. policies. Foremost is the principle that the main responsibility for ensuring that highly skilled people either do not emigrate or do return after studies abroad rests with the countries of origin. If severe restrictions on the free movements of people must be imposed, they can be imposed more easily at the point of departure than after the arrival in the United States. At the same time, however, the United States can assist foreign countries in keeping track of its foreign nationals and helping to bring to justice individuals convicted by due process of law in these countries. Such cooperation would leave the initiative for and choice of specific policies to foreign official agencies knowing best the needs of their countries and the amount of personal sacrifice and subjection they can demand from their own citizens in the name of nationalism.

The United States government, by unilateral action, can change the size and composition of its foreign-assistance programs entailing the formation of human capital. The argument about gross and net cost of U.S. student exchange that I have just presented suggests that Congress should consider the net figure, rather than gross expenditure, as the relevant target when it decides the magnitude of foreign-aid appropriations (*12*). Alternatively, the United States can change the composition of its international program of education, by reduction in the number of foreign students in the United States and increase in the number of U.S. teachers and professors abroad. Shifts of this nature may be limited, to the extent that training abroad is an imperfect substitute for schooling in the United States, since the latter includes direct exposure to U.S. culture and institutions, which are considered important by many proponents of international-exchange programs.

The U.S. government can furthermore act unilaterally to remove domestic imbalances in the demand and supply in some professional fields, especially the medical. Sharp increase in the output of medical schools would be socially desirable on many grounds other than its effects on the immigration of foreign medical personnel.

It is at the nongovernment level, however, that the United States can cope most effectively with the problem of the brain drain. Private individuals, as teachers of foreign students, can encourage them to return home by awakening and nurturing patriotic sentiments and by refraining from offering them employment and opportunities for complete integration into U.S. academic, institutional, and social structures. Teachers here are free to balance the advantages and disadvantages of each decision in their own minds, closely comparing a gifted student's possible contribution to knowledge through research in the United States to the use to which his talents might be put in his native country. A teacher's advice regarding a student's curriculum should be geared closely to his country's needs, without, however, stifling his special talents and interests.

Most foreign commentators on the brain-drain problem point to inhospitable intellectual, political, social, and institutional climates in native countries, rather than lower wages, as the main causes of the reluctance of students to return (*13*). American social scientists, and intellectuals in general, can have an important influence on the future environment and institutions in these countries through scholarly analysis of their shortcomings and advantages and through constructive suggestion of alternatives. Influencing foreign intellectual life and institutions is definitely not the role of the U.S. government, and, although the process of change through private scholars and by the indication of alternatives may be discouragingly slow, it is the only sure method of producing durable new institutions and customs suited to the need of each country. The nonreturn of students and the emigration of high-level manpower are in themselves powerful forces creating demand for changes.

United States charitable foundations as private agencies can, through appropriate subsidies and programs of expenditure, create incentives for changes in the environments of foreign countries along the lines suggested by U.S. scholars in consultation with progressive elements of these countries' intellectuals—which may well include returned students. The U.S. foundations, independent of the government and held in high regard in most countries, are uniquely suited to carry on these types of programs.

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NEWS AND COMMENT

Grant Swinger: Reflections on Six Years of Progress*

The genesis and history of the National Animal Speech Agency (NASA) are too well known to require detailed treatment before this audience. But, as one who has been privileged to witness the development and growth of this remarkable organization, I believe it would be useful to set forth a few points that perhaps have been overlooked in the general rush of events.

As will be recalled, NASA's incredible growth had its origins in the President's challenge to the nation "to teach an animal to speak in this decade." It has been contended, of course, that the challenge was simply a device to divert attention from the failure of certain foreign ventures. But a more realistic view, I contend, is that both the presentation and the acceptance of this challenge were inevitable consequences of national dynamics. Clearly, any nation that aspires to greatness cannot assent to a subordinate position in a technology so rich in military, economic, and cultural implications.

Be that as it may, the fact is that the acceptance of the challenge released a stream of energies of unparalleled dimensions in our nation's history. Let us briefly consider just a very few of the multitudinous consequences of that decision. "To teach an animal to speak in this decade" is a goal that can be stated in less than a breathful of words, but, as we are all well aware, it is a goal whose attainment has required a marshaling of effort and excellence that is remaking the nation.

Look back, for example, at the uncertainties that faced those few administrators, scientists, and engineers who courageously developed this proposal. Teach an animal to speak. Yes, but which animal? And what should the animal be taught to say? At the present time, when we estimate that we are two-thirds along the way in this great national undertaking, such questions seem elementary and remote. But it is necessary to recognize that just a very few years ago these questions symbolized matters of the greatest uncertainty. Fortunately, the nation had the services of several men of great foresight, courage, and experience to lead the way. For, let us not forget those skillful few who, in now happily forgotten days of strife, had pioneered in this great work. To our great gain, in those bygone days they had developed a primitive technology of animal speech. This speech, it must be acknowledged, was of the most scurrilous, vituperative, and vile nature, but it is difficult to argue with the explanation that in those long-ago circumstances the men who taught animals to speak could not be held responsible for what the animals chose to say.

Now, there is no need to dwell on the vast amount of uninformed carping that has been directed at this program. Success, needless to say, speaks for itself, but, if Project Mother Goose had to defend itself, there would of course be no difficulty in justifying the admittedly vast expenditures that it has entailed. In terms of pushing back the frontiers of knowledge, the project has been an unprecedented boon to virtually every scientific discipline. The initial phase, as we all know, required the collaborative efforts of zoologists and geographers to inventory the possible subjects; psychologists, physiologists, and linguists to develop a theory of animal speech; audio-engineers, biologists, and veterinary surgeons to tackle the once seemingly impossible problems of somatic reconstruction necessary for success. Out of these efforts have come many intellectual triumphs, not the least of which is a new scientific discipline, low-temperature linguistics; while the objectives, methods, and purposes of this new field of scientific pioneering are yet to be determined, its work proceeds at a rapid pace, for which we are all grateful.

And let us not forget the great variety of other disciplines that have been drawn into the project: the legal scholars, for example, who, with great foresight, have been wrestling with the problem of the admissibility of animal testimony in legal proceedings. All these efforts, needless to say, have spun off valuable products and techniques of immeasurable worth to the nation's economy. In fact, if the project can claim no more than invention of the reusable tongue depressor, now in an advanced stage of development, it will have more than paid for itself in social worth.

Under the newly established University Program for the Comprehensive Handling and Utilization of Knowledge, known as Project UPCHUK, we are diligently searching for still other applications of the knowledge that has been specifically developed for Mother Goose.

Furthermore, how can one compute in dollars the value of the scientific stimulation that has resulted from the

* Dr. Swinger is director of the Breakthrough Institute and chairman of the Board of the Center for the Absorption of Federal Funds. This article was adapted from his address at the Center for Intellectual Evanescence, where he received the Hunter von Tenure award for his monograph "Overhead and Underhand: The Economics of Academic Research."