FOREIGN MANPOWER IN THE U.S. SCIENCES

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Because of the recent public concern over the brain drain, this study attempts to measure the U.S. gain of highly skilled manpower. The paper discusses the serious shortcomings of the data on gross immigration of scientists and engineers provided by the U.S. immigration authorities as a measure of true U.S. gains. In a case study of Swedish scientists and engineers it was found, for example, that whereas the U.S. data showed a gain of 106 Swedish scientists and engineers over a number of years, the net figure was only 26 after adjustment for remigration and the application of the proper OECD education criteria.

The paper then reports the findings of a statistical study which uses the stock data on U.S. scientists in the National Register of Scientific and Technical Personnel to estimate the number of foreign born in this stock and analyse their characteristics with respect to age, educational attainment, and employment preferences.

It was found that nearly 7 percent of all U.S. scientists are of foreign origin (foreign born and foreign secondary education), whereas 11.5 percent of all scientists with a Ph.D. are of foreign origin. The percentage among Ph.D. holders is highest in meteorology (22.3), followed by linguistics (18.7), physics (17.1) and statistics (14.6).

The greatest percentage of scientists comes from Canada (10.4 per thousand), followed by Germany (8.3 per thousand) and the United Kingdom (6.7 per thousand). However, after adjustment of these data for the different sizes of the total foreign born population from each country in the U.S., it turns out that by this measure the greatest shares of scientists are supplied by the Japanese, followed by the Austrian-Swiss, Benelux and Canadians.

The analysis of the age composition of all foreign born reveals that in the age groups that were 20–29, 45–54, and 65 and over in 1964 foreigners represent a smaller than average share, probably reflecting war casualties and education completed at a later age. Germans and Austrians are heavily concentrated in the group 55–64 years old in 1964, suggesting that a great share of scientists from these countries may have been victims of a brain push.

Much of the recent public discussion about the international flow of highly skilled manpower to the United States, popularly known as the "brain drain," is based on very little concrete evidence about the actual magnitude of the flow. The reason for this lack of knowledge is that existing methods of collecting statistics about migration have not been designed to cope with the specific problem of counting highly skilled migrants. Thus, for example in the United States the Immigration and Naturalization Service which keeps all records about immigrants had to engage in a special study to tabulate the numbers of scientists and engineers who had immigrated in recent years.

These statistics have been analysed,[1] but their usefulness is strictly limited by three characteristics. First, the immigrants' occupational characteristics are ambiguous. The forms filled out by the immigrants do not define the occupations

1. See Herbert G. Grubel and Anthony D. Scott, "The Immigration of Scientists and Engineers to the United States, 1949–61," *Journal of Political Economy*, August, 1966, and Thomas J. Mills, "Scientific Personnel and the Professions," *The Annals of the American Academy of Political and Social Science*, September, 1966.

The sources also contain precise references to the data compiled by the Immigration and Naturalization Service and published by the National Science Foundation in several places.

engineer, technician, biologist, economist, etc., either in terms of education or work experience. In general, immigrants to the United States can be assumed to have an incentive to overstate their professional qualifications in their dealings with immigration authorities because of the well-known discrimination of the U.S. laws in favor of highly skilled persons. However, the degree of actual overstatement is not known.

Second, the immigrants indicate their professional qualifications at the time they apply for an immigrant's visa. Thus, the available data cannot discriminate between individuals fully educated abroad and individuals who came to the United States as students and attained immigration status only after completion of their education. For purposes of analysing the effects of the brain drain the former persons definitely need to be distinguished from the latter.

Third, identification of highly skilled people by the type of visa under which they stay in the United States does not mean that temporary visitors and permanent immigrants have been distinguished successfully. Some persons enter the United States as students or under visas granted to temporary visitors, even though they plan to become permanent immigrants at a later stage, most often when age or family status assure draft exemption. By this method young men are able to avoid U.S. military service since visitors on temporary visas are not subject to the draft. On the other hand, there are many highly skilled individuals (beyond draft age) who enter the United States on immigrant visas even though they intend to stay only temporarily as students, trainees, professors, or interns, simply because U.S. laws governing employment of visiting aliens are restrictive and administratively burdensome for holders of temporary visas. Because of the lack of data on the professional qualifications of emigrating U.S. residents, there exists no way to adjust the gross immigration data to take account of the subsequent departures of people who had entered at one time as "immigrants."

For these reasons, data on the flow of highly skilled persons collected by the U.S. immigration authorities are of limited value.[2] It is not clear whether these authorities can be encouraged to perfect their techniques of gathering and publishing information on the occupational characteristics of people entering the United States. At best, however, such data can be useful only in interpreting

2. Recently some evidence has become available which suggests that these immigration statistics are not only inadequate, but highly misleading if they are used to measure the value of resources accruing to the United States through the movement of highly skilled people. The U.S. immigration statistics show that during the period 1957–61 on the average annually 106 scientists and engineers immigrated to the United States from Sweden (Grubel and Scott, *op. cit.* p. 372). The careful analysis of Swedish statistics for nearly the same period by Goeran Friborg, published in "International Movement of Scientific and Technical Personnel: Notes on OECD Migration Study Based on the Preliminary Analysis of National Data," mimeographed, 1966, shows Sweden's average annual net loss only at 25 rather than 106. This reduction is due, first, to the elimination of all individuals whose educational level is below the university degree and of persons for whom Sweden was merely a country of last permanent residence (45 persons), and second, to the accounting for the return migration of Swedish scientists and engineers from the United States, averaging 36 per year. It should be noted that this number of returnees will increase through time if a constant proportion of emigrants return, since the gross number of emigrants has been rising. If that trend would level out or become negative, then future net migration figures will be smaller than the ones computed for the late 1950's.

recent flows and will not enable us to put them into an historic perspective for some time to come.

Fortunately, an alternative method of measuring recent and historic flows of highly skilled persons to the United States has become available. This method makes use of data on stocks rather than flows and uses as basic raw material the information on U.S. highly skilled manpower recently collected by the U.S. National Science Foundation. The data, known as the National Register of Scientific and Technical Personnel, have been designed primarily to aid governmental decision making in the areas of man-power planning, education and research policies. However, the information about scientists' personal, educational and professional backgrounds are such that the Register can be used to provide a detailed analysis of the extent to which the U.S. scientific and technical professions depend on persons born and trained in foreign countries.

In the following part of this paper I present a description of the data contained in the Register and how they are collected. An analysis of the 1964 data is presented in Part II. The analysis is limited by the availability of compilations made by the National Science Foundation, but I hope to evoke suggestions for further analysis, which I will take into consideration in a future study to be based on the complete set of raw data from the 1966 Register.[3]

I. National Register Data

The National Register of Scientific and Technical Personnel was begun in 1954 and through evolution and expanded coverage reached the form and magnitude of the 1964 registration to be described.

The Questionnaire

The questionnaire asked scientists to indicate, among other things, their place and date of birth, place of secondary education, and the dates and levels of their college, university and professional degrees and the institutions and countries where they obtained them. Also,the questions concerned the type of current employment and the level of professional income. Responses of persons are coded by social security number, which will be used for studies tracing persons' careers through time. Such a "longitudinal" file is now being prepared.

Unfortunately, the question concerning citizenship status does not ask for the date of first entry or immigration to the United States, or the date when citizenship was granted. For the analysis of the brain drain it is rather important to have these data collected and it is hoped that the producers of the Register can be convinced to alter their questionnaire along these lines in the future. However, the present data do permit some limited insights into a person's arrival in the United States. Thus, for example, a person with foreign birth and completed foreign secondary education but U.S. college and professional degrees

3. The basic compilations used in this study were prepared by the National Science Foundation for an OECD sponsored study and were made available to me. Thomas Mills has published some of the findings in the article cited in footnote one. I have combined those data on the persons of foreign origin with the published compilations found in *American Science Manpower 1964*, National Science Foundation NSF 66–29, Washington, 1966. Unfortunately the data on foreigners did not contain compilations of income statistics.

must have come to the United States after high school graduation and before college. The approximate time of the migration can be inferred from the dates on which the various steps of training were completed.

Coverage of Professions

The 415,000 persons surveyed in the 1964 Register were identified by the National Science Foundation with the help of cooperating professional societies. The names of the surveyed were obtained from the membership lists of professional societies, supplemented by names of recent graduates with baccalaureate degrees, subscribers to professional publications, and non-member registrants at professional meetings. Efforts were made to eliminate duplication of names.

Of the 415,000 mailed questionnaires 265,000, or 64 per cent, were returned. Special studies of the characteristics of the non-respondents are now under way.

The 265,000 returned questionnaires were examined by representatives from the individual professional societies to establish whether the individuals met their eligibility criteria as members of "full professional standing". The eligibility criteria vary among societies. The American Chemical Society, for example, considers a person to be a chemist if he has a bachelor's degree in chemistry and if he is employed in a position requiring a knowledge of chemistry. On the other hand, the Federation of American Societies for Experimental Biology considers someone to be an experimental biologist only if he holds a doctorate degree and has several years of research experience. It is not known what bias these differing criteria between scientific disciplines introduce into the analysis of Part II. However, since very high education criteria eliminate some individuals who elsewhere or under different circumstances might be considered members of the profession, and since the foreign born appear to be more highly educated than the average, the stricter the education criteria the greater the tendency for an overstatement of the role of foreigners in these professions.

As a result of the screening by professional societies and through the elimination of incomplete questionnaires, 41,000 answers were discarded so that the 1964 Register contains information on 224,000 scientists. It has been estimated that this Register includes 90 per cent of the Nation's science doctorates, and about 75 per cent of the population of "scientists with full professional standing."[4]

Respondents were classified as chemists, physicists, economists, etc. according to their own indication of their field of greatest scientific competence. This classification may differ from one arrived at by consideration of academic training or job title. For the purposes of the present analysis the method of classification is not important as long as it is applied consistently to foreign and U.S. scientists.

Foreigners in this paper are defined as persons who are of foreign birth and have foreign secondary schooling, which is the OECD adopted definition of persons of "foreign origin". This classification excludes persons of foreign birth and complete U.S. education, as well as those of foreign birth and with

4. NSF 66–29, *op. cit.*, p. 2.

primary education abroad. In a previous, more detailed study of economists alone it was found that while 12 per cent were born abroad, about 9 per cent were of foreign origin as defined.[5] When persons were born in one country but completed their secondary education in another, they were counted as originating from the country where they completed their secondary education.

II. Scientists of Foreign Origin

Foreigners in Individual Disciplines

Table 1 of the text presents the most basic information about the numbers and shares of scientists of foreign origin in the United States, broken down by 13 different disciplines and countries of origin. In order to keep the text from becoming too cluttered with numbers I have relegated to the Appendix a table analogous to Table 1 but showing the numbers of all Ph.D. scientists in the United States and shares of Ph.D.s of foreign origin.

From Table 2 it can be seen that the foreigners represent 6.9 per cent of all scientists and 11.5 per cent of all Ph.D.s in the United States. However, it should be noted here that the data available for this study do not indicate where the persons of foreign origin received their professional training. My previous analysis of economists indicated that only about one third of people with foreign origin also had obtained their professional training abroad.

In general the greater proportion of foreign born among the more highly skilled supports the notion that mobility is greater the higher the level of education, for which theoretical reasons have been adduced elsewhere.[6]

As for the ranking of scientific disciplines according to the share of foreigners, it comes as no great surprise to find that linguists rank first at 18.9 per cent of all U.S. linguists, because of the comparative advantage foreigners enjoy in the knowledge of their native languages. In contrast with the other disciplines, however, there is an interesting decline in the foreigners' share among linguists with a Ph.D. It appears that the scientific skills required at this level depend to a lesser degree on the mechanical language skills, in which natives have their greatest advantage, than does work at different levels. An examination of the national origin of linguists shows an overwhelming preponderance of Germans, even though the German language teaching in U.S. high schools and universities is smaller than that of French and Spanish. This phenomenon must be due to special conditions of supply in Germany. At the same time it is noteworthy that there are only 2, 3 and 4 Ph.D. linguists who are of French, Spanish-Portuguese and Greek origin, respectively.

On the theoretical grounds one would expect the share of foreigners in individual disciplines to be greater the more universal the discipline's stock of knowledge and the less country-specific the skills. This is so because the more universal the basic tools and knowledge the more unified and better informed is

5. See Herbert G. Grubel and Anthony D. Scott, "The Characteristics of Foreigners in the U.S. Economics Profession," *American Economic Review*, March 1967.

6. See Herbert G. Grubel and Anthony D. Scott, "Determinants of Migration: The Highly Skilled," *International Migration*, forthcoming.

TABLE 1

ALL SCIENTISTS OF FOREIGN ORIGIN,
BY COUNTRY OF SECONDARY EDUCATION AND SCIENTIFIC FIELD

Countries of Secondary Education	Total		Chemistry		Earth Sciences		Meteorology		Physics		Mathematics		Agricultural Sciences	
	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand
Austria, Switzerland	1,077	4.8	409	6.5	40	2.2	10	1.8	163	6.1	72	4.1	4	0.4
Benelux	494	2.2	139	2.2	45	2.5	5	0.9	91	3.4	36	2.1	13	1.4
Canada	2,326	10.4	626	9.9	145	8.1	24	4.4	311	11.6	225	12.9	95	10.0
Scandinavia	310	1.4	90	1.4	10	0.6	9	1.6	50	1.9	34	2.0	7	0.7
France	231	1.0	46	0.7	12	0.7	1	0.2	48	1.8	29	1.7	1	0.1
Germany	1,865	8.3	610	9.7	46	2.6	37	6.7	390	14.6	117	6.7	17	1.8
Greece, Yugoslavia	388	1.7	145	2.3	6	0.3	4	0.7	56	2.1	33	2.0	1	0.1
Great Britain	1,505	6.7	482	7.6	75	4.2	18	3.3	331	12.4	124	7.1	20	2.1
Italy	285	1.3	94	1.5	4	0.2	0	0.0	45	1.7	21	1.2	1	0.1
Spain, Portugal	74	0.3	18	0.3	4	0.2	2	0.4	16	0.6	4	0.2	0	0.0
Japan	486	2.2	131	2.1	12	0.7	17	3.1	110	4.1	52	3.0	2	0.2
Turkey	106	0.5	25	0.4	10	0.6	1	0.2	26	1.0	6	0.3	2	0.2
All O.E.C.D.	9,147	40.9	2,815	44.6	409	22.8	128	23.2	1,637	61.3	753	43.2	163	17.1
All Other	6,387	28.5	2,102	33.3	257	14.4	82	14.9	1,020	38.2	515	29.6	134	14.1
Total Foreign	15,534	69.4	4,917	78.0	666	37.2	210	38.1	2,657	99.5	1,268	72.8	297	31.2
All Scientists in U.S.	223,854	1000	63,053	1000	17,907	1000	5,510	1000	26,698	1000	17,411	1000	9,526	1000

TABLE 1 (*Concluded*)

ALL SCIENTISTS OF FOREIGN ORIGIN,
BY COUNTRY OF SECONDARY EDUCATION AND SCIENTIFIC FIELD

Countries of Secondary Education	Biological Sciences		Psychology		Statistics		Economics		Sociology		Linguistics		All Other Fields	
	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand
Austria, Switzerland	135	5.0	76	4.5	6	2.1	79	6.5	12	4.4	16	11.8	55	2.6
Benelux	76	2.8	17	1.0	6	2.1	28	2.3	8	3.0	5	3.7	25	1.2
Canada	406	15.0	161	9.6	29	10.2	138	11.4	29	10.7	17	12.6	120	5.8
Scandinavia	50	18.4	12	0.7	3	1.1	17	1.4	3	1.1	8	5.9	17	0.8
France	31	1.1	8	0.5	3	1.1	19	1.6	4	1.5	6	4.4	23	1.1
Germany	229	8.4	109	6.5	14	4.9	137	11.3	40	14.8	29	21.5	90	4.3
Greece, Yugoslavia	48	1.8	14	0.8	7	2.5	43	3.5	9	3.3	7	5.2	15	0.7
Great Britain	209	7.7	57	3.4	17	6.0	72	5.9	22	8.1	14	10.4	64	3.1
Italy	67	2.5	8	0.5	0	0.0	17	1.4	5	1.8	7	5.2	16	0.8
Spain, Portugal	20	0.7	1	0.1	0	0.0	4	0.3	1	0.4	3	2.2	1	0.0
Japan	103	3.8	12	0.7	5	1.8	16	1.3	3	1.1	9	6.7	14	0.7
Turkey	12	0.4	7	0.4	1	0.4	6	0.5	1	0.4	0	0.0	9	0.4
All O.E.C.D.	1,386	51.1	482	28.7	91	32.0	576	47.4	137	50.7	121	89.6	449	21.6
All Other	915	33.7	234	13.9	141	49.6	415	34.2	103	38.1	134	99.2	335	16.1
Total Foreign	2,301	84.8	716	42.6	232	81.6	991	81.6	240	88.8	255	188.7	784	37.7
All Scientists in U.S.	27,135	1000	16,804	1000	2,843	1000	12,143	1000	2,703	1000	1,351	1000	20,770	1000

Source: Compilations by National Science Foundation from 1964 Register of Scientific and Technical Personnel. Data on Foreigners, special unpublished compilations. Data on total U.S. stock of scientists were taken from *American Science Manpower 1964*, National Science Foundation, NSF 66-29, Washington, 1966.

Notes: All Other Fields includes: Abstracting, Anthropology, Archeology, Education, History, Music, etc., as well as some Engineering. Precise breakdowns are not available.

the world market for individuals in these fields. Contributions to the science are judged by internationally comparable standards and outstanding individuals in all countries are recognized and very frequently are tempted to move to join other colleagues or work for higher pay. In addition, the personal investment required of the individual scientists as a preparation for work in a new environment is smaller the more universal the discipline's tools and stock of knowledge.

These considerations are born out quite strongly by the ranking of disciplines by shares of Ph.D.s. As can be seen from Table 2, meteorology, physics,

TABLE 2

SCIENTISTS OF FOREIGN ORIGIN AS SHARE OF SCIENTIFIC DISCIPLINES

	Foreign Origin as Per Cent of All Scientists	Foreign Ph.D.s as Per Cent of All Ph.D.s
Linguists	18.9	18.7
Physics	10.0	17.1
Sociology	8.9	9.3
Biological Sciences	8.5	8.8
Economics	8.2	11.8
Statistics	8.2	14.6
Chemistry	7.8	13.8
Mathematics	7.3	7.3
Psychology	4.3	5.0
Meteorology	3.8	22.3
All Other Fields	3.8	10.0
Earth Sciences	3.7	9.4
Agricultural Sciences	3.1	6.2
All	6.9	11.5

Source: Table 1 and Appendix, Table 1

statistics and chemistry have the greatest shares of foreigners and meet the theoretical criteria. However, the theory is not supported by the data for one of the most universal of all fields, mathematics, where the share of foreigners is relatively small at 7.3 per cent. These findings about mathematicians and Ph.D. linguists suggest that any general theory about the movement of highly skilled people must be modified in specific cases by special considerations of demand and supply in both the net gaining and net losing countries.

Such careful analysis of the detailed data is extremely important for national policies designed to cope with the brain drain. For example, the relatively large number of German linguists in the United States may be due to a German cultural tradition or the existence of strong and persuasive teachers in this field, which has resulted in what could be considered to be an excess supply of language teachers and scholars in Germany. If this explanation is correct, and I am not certain that it is, then the movement of German linguists to the United States is a safety valve aiding the correction of a supply disequilibrium that benefits those who have made a human capital investment in the skill and the U.S. public which ends up with lower cost language teaching. In a broader framework still,

such a situation may even be considered not to be a disequilibrium, but the manifestation of Germany's comparative advantage in the production of linguists with all the welfare implications which international specialization and exchange are known to bring to the participating nations. Similar considerations may be applicable to the remarkably large share of Ph.D. meteorologists of German origin and more detailed analysis of the data coupled with knowledge about conditions in specific disciplines is bound to reveal other disequilibria in demand or supply or special national advantages in training.

Shares of Individual Countries

The first column of Table 1 shows the number of scientists of foreign origin which were contributed by the individual countries. As can be seen, Canadians have been the most important contributors with 2,326, followed by Germany with 1,865, Great Britain with 1,505 and Austria-Switzerland with 1,077. All other OECD countries individually contributed fewer than 1,000 persons, while U.S. scientists of OECD origin altogether amounted to 9,147. All other foreigners, which include large numbers of East-Europeans, and all the underdeveloped world, contributed 6,387. Detailed breakdowns of the last group of countries are not available, but for economists alone Africa contributed 2 per cent, Asia 15 per cent, South America 1 per cent and East Europe 20 per cent of all foreign-born.[7]

The order of countries' importance according to this basic classification is shown in Table 3, where in column (1) the absolute numbers have been expressed as per thousand of all U.S. scientists. As can be seen, according to this base, 10.4 out of every 1,000 U.S. scientists are of Canadian origin while only 3 in every 10,000 are from Spain or Portugal. Column (2) of the same table shows that the ranking of countries is essentially unchanged if their natives' shares in the group of Ph.D. holders is considered.

While these raw numbers and basic shares are of some interest, they say very little about the consequences and nature of the migration of these highly skilled people. For example, the fact that only two per cent of all economists of foreign birth in the United States are from Africa may indicate a more severe loss in terms of national development and efficiency of decision-making in government in that continent than does the loss of 97 British economists, who represent 8 per cent of all foreign born,[8] for the efficiency of the United Kingdom's government decision making processes. As the example suggests, therefore, one would want to put the number of highly skilled emigrants in relation to the size of their nations' scientific manpower stock. Such an analysis could not be undertaken, because the national data on stocks of scientists are imperfect. Some countries have no data, some have non-comparable coverages, some had to be consolidated because of the national breakdown of the NSF data used in this paper, so that I did not find the available data useful for this analysis.[9]

7. Grubel and Scott, *American Economic Review*, *op. cit.*
8. *Ibid.*, p. 137.
9. The OECD has collected some statistics on the size of stocks of scientists in *"Resources of Scientific and Technical Personnel in the OECD Area."* The numbers of observations I felt I could trust were simply too small to permit any meaningful analysis.

TABLE 3

SHARES OF INDIVIDUAL COUNTRIES

Countries	Foreign Scientists per thousand All U.S. Scientists (1)	Foreign Ph.D.s per thousand U.S. Ph.D.s (2)	All Foreign-Born per thousand U.S. Population (3)	(1)÷(3) (4)	(2)÷(3) (5)	Foreign-Born Scientists per thousand All Foreign-Born (6)	Foreign-Born Scientists per million Native Population (7)
Canada	10.4	18.7	5.31	2.0	3.5	2.4	125.1
Germany	8.3	15.3	5.52	1.5	2.8	1.9	33.9
Great Britain	6.7	11.9	4.65	1.4	2.6	1.8	28.2
Austria, Switzerland	4.8	9.5	2.04	2.4	4.7	2.9	84.1
Japan	2.2	4.4	0.61	3.6	7.2	4.3	5.1
Benelux	2.2	3.9	1.08	2.0	3.6	2.6	23.5
Greece-Yugoslavia	1.7	2.3	1.81	0.9	1.3	1.2	14.2
Scandinavia	1.4	1.9	2.50	0.6	0.8	0.6	19.4
Italy	1.3	2.1	7.01	0.2	0.3	0.2	5.7
France	1.0	1.6	0.62	1.6	2.6	2.0	4.9
Turkey	0.5	0.6	0.29	1.7	2.1	2.0	3.6
Spain, Portugal	0.3	0.4	0.57	0.5	0.7	0.7	1.9
All O.E.C.D.	72.6	40.9	37.33	1.1	1.9	1.4	19.0
All Other	42.5	28.5	17.22	1.7	2.4	2.0	2.4
Total Foreign	115.1	69.4	54.56	1.3	2.1	1.6	5.0

Sources: Column 1: Table 1.
Column 2: Appendix Table I.
Column 3: U.S. Census of 1960, Summary, PC(1), p. 366.
Column 7: Population of Countries from United Nations *Statistical Yearbook*.

Note: The figure for Germany in Column 7 is for West Germany only; if East Germany is included the figure falls to 26.3

Instead, I introduced some other, second-best measures which bring these national data into perspective. In column (3) of Table 3 I present data which show how many natives of the individual countries there were per thousand of U.S. population, according to the U.S. Census of 1960. With the notable exceptions of Italy and Scandinavia, the ranking of countries in column (3) is nearly identical to that of columns (1) and (2). Thus, to a large extent the significant shares of Canadian, German and British scientists in the U.S. scientific manpower go together with a relatively large scale of general immigration to the United States.

However, as columns (4), (5) and (6) show, there are some interesting national differences in the proportions in which foreign-born residents of the United States are scientists. Thus, 4.3 per thousand Japanese are scientists, while the next highest shares are held by the Austrian-Swiss (2.9 per thousand) and individuals from the Benelux (2.6 per thousand). According to these statistics, persons born in Turkey living in the United States have as many scientists per thousand as do the French, and more than the Germans and British.

Column (4) is an index which expresses how much more a person of a given national birth is likely to be a scientist than is a person of U.S. birth. Column (5) presents the same index for Ph.D.s in science alone. As can be seen from the data, if in the United States one meets a person of Japanese birth, he is seven times more likely to be a Ph.D. than any U.S. person met randomly. It is naturally no coincidence that the countries ranked according to this index should appear in the same order as they were ranked for the magnitudes found in column (6), i.e. the proportion of each country's natives in the United States which have become scientists.

It is interesting to speculate about the reasons why the foreign-born in the United States have a greater propensity to become scientists than do the Americans. The first explanation is purely statistical in the sense that the U.S.-born population contains a greater proportion of young persons than does the foreign-born population. Some evidence along these lines is introduced below. In common sense terms this age differential means that the number of U.S. born scientists per thousand population is lowered because the general population includes children and students whereas for the foreign-born this is not the case. Unfortunately the available data do not permit precise qualification of this effect. However, according to the available information I would judge the influence of the age-composition not to be an overwhelming factor in the explanation of the phenomenon.

Instead, I would attach great weight to the explanation that the U.S. immigration laws discriminate in favor of the highly skilled. This factor appears to be especially significant in the case of Japan, since the basic immigration quotas are very small for the Asian countries. But in addition to the influence of the laws, we also observe the working of the aforementioned greater propensities of highly skilled persons to move, both permanently and temporarily. As a result of the temporary movements a certain, though unknown, proportion of those counted as foreign-born members of the U.S. scientific manpower may be transients only.

Third, there may be a sociological-psychological phenomenon at work. As is well known, persons of racial and religious minorities have often found it possible to avoid discrimination in society by entering professions where objectively measurable performance, such as scientific papers, discoveries, etc., determine advancement. One important entrance into these types of employment is provided by education. This incentive may well have contributed to the observed great propensity for Americans of foreign origin to earn the Ph.D. and enter the sciences.

Unfortunately I have been unable to develop any theoretical model which would, with the available data, allow me to quantify the relative importance of these three reasons for explaining the preponderance of foreign-born in U.S. science manpower, even though this kind of information would be very valuable for persons who wish to formulate policies for influencing the brain drain.

In the last column of Table 3 I introduce one more set of information which serves to put into perspective the national contributions to scientific manpower in the United States. Column (7) shows that on the basis of native population, the Canadian contribution is by far the most significant, amounting to 125 scientists of Canadian origin in the United States for every one million of Canada's population. Second on this scale is Austria-Switzerland with 84 per million, followed by West Germany (34 per million)[10] and Great Britain (28 per million). France, Italy and Spain-Portugal are remarkably low in comparison with the Anglo-Saxon and Scandinavian countries.

A similar analysis adjusting the national shares of individual scientific disciplines for the size of scientists' countries of origin would also be useful in understanding the brain drain. Thus, for example, if the contribution of Austrian-Swiss linguists is adjusted for the population size of Austria and Switzerland, it looms more important than that of Germany, which is more noticeable by its absolute size. Thus the comments made about German linguists applies to Austrian-Swiss linguists with greater force.

While in general it is true that the numbers of emigrated scientists per million of native population are a better measure of the importance of the brain drain for individual countries than are the absolute numbers, it should also be remembered that these data represent gross losses which are unadjusted for gains of manpower from the United States and the rest of the world. Thus in other studies, for example, Canada has been found to be a net gainer of highly skilled persons from the rest of the world in spite of her losses to the United States.[11] More specifically, there are more U.S.-born and -trained economists teaching in Canada than there are Canadian-born and -trained economists teaching in the United States.[12] Unfortunately stock data such as those in the

10. This figure is for West Germany alone. For West plus East Germany, the figure falls to 26.3, still 4th highest. It should also be noted here that Canada's contribution is overstated by the extent to which natives of other countries have only a Canadian secondary school degree, and therefore are counted as being of "Canadian origin." Canada has been a traditional country for many immigrants to enter before coming to the United States.

11. Louis Parais, *Immigration and Emigration of Professional and Skilled Manpower During the Post-War Period*, Special Study No. 1, prepared for the Economic Council of Canada, Ottawa, 1965.

12. According to a survey analysed in Anthony D. Scott and Herbert G. Grubel, "The International Migrations of Canadian Economists," mimeographed, 1966.

National Register of Scientific and Technical Personnel do not permit inferences of this nature, which depend on the collection of similar data in other countries.

Age Distribution

In Table 4 I present data on the age-distribution of U.S. scientists of foreign origin and compare it with that found for all scientists.

The most notable feature of the data is that for the groups that were 20–29, 45–54 and 65 and over years old in 1964, foreigners represent a smaller than average share. In the case of the youngest age group I offer the speculation that it reflects the generally higher levels of education of foreigners discussed earlier, which normally is concluded only around age thirty. The individuals who were 50–54 in 1964 are part of the generation that bore the brunt of World War II casualties since they were 25 to 29 years of age at the outbreak of hostilities in 1939, and war deaths were proportionately greater in Europe than in the United States. In addition, that generation had its education interrupted by the War and severely curtailed by the chaos of the post-war years.

The relatively heavier representation of foreigners in the group of those 55–64 years old in 1964 is especially pronounced for Germans and Austrians. This fact suggests the hypothesis that these scientists represent to a large measure the young professionals who were 26–35 years of age when Hitler's persecution of minorities approached its peak in 1935. If the hypothesis is correct, then for these age groups at least, which in turn make up a significant share of foreign scientific manpower in the United States, it is false to speak of a deplorable U.S. "brain drain," and it would be much more just to consider it the result of a European "brain push."

In general I believe that the detailed analysis of the time pattern of past migration, preferably built on information about the date of first entry into the United States, can add significantly to our understanding of the causes and nature of the international flow of highly skilled persons, necessary before intelligent policies can be made to remedy whatever inequities or inefficiencies are found to result from it.

III. Conclusions

In conclusion I would like to point to some further analysis that can be undertaken with the basic raw data in the National Register of Scientific and Technical Personnel.

First, there is the analysis of professional incomes. These permit us to make inferences about the "value" of foreign education and the "quality" (as measured by income) of the services provided by foreign born and foreign educated scientists in comparison with those provided by persons with a complete U.S. background.

Second, one can analyse the work-preferences of foreign and U.S. scientists. One hypothesis to be tested is whether foreigners tend to concentrate in research and teaching over such work as sales, management and government, where "output" is more difficult to measure objectively and where the required contact with the public may be made more difficult by residual language problems and resentment of foreigners.

TABLE 4

FOREIGN BORN SCIENTISTS
PER THOUSAND U.S. SCIENTISTS IN AGE GROUP

Countries	20 — 24		25 — 29		30 — 34		35 — 39		40 — 44		45 — 49	
	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand
Austria, Switzerland	1	0.1	33	0.9	123	3.1	179	4.5	204	5.7	138	5.6
Benelux	4	0.5	31	0.9	96	2.4	99	2.5	99	2.8	55	2.2
Canada	34	4.1	237	6.9	335	8.4	426	10.6	445	12.4	299	12.1
Scandinavia	1	0.1	21	0.6	52	1.3	59	1.5	65	1.8	41	1.7
France	3	0.4	23	0.7	34	0.9	44	1.1	62	1.7	14	0.6
Germany	5	0.6	60	1.8	286	7.2	394	9.8	254	7.1	156	6.3
Greece, Yugoslavia	3	0.4	40	1.2	99	2.5	92	2.3	79	2.2	30	1.2
Great Britain	24	2.9	261	7.7	334	8.4	319	7.9	237	6.6	102	4.1
Italy	0	0.0	28	0.8	44	1.1	77	1.9	61	1.7	27	1.1
Spain, Portugal	1	0.1	5	0.1	12	0.3	18	0.4	14	0.4	11	0.4
Japan	0	0.0	30	0.9	159	3.7	166	4.1	84	2.3	22	0.9
Turkey	1	0.1	12	0.4	24	0.6	23	0.6	18	0.5	11	0.4
All O.E.C.D.	77	9.3	781	22.9	1,598	40.0	1,896	47.2	1,622	45.3	906	36.6
All Other	105	12.7	1,059	31.1	1,468	36.8	1,248	31.1	982	27.4	559	22.6
Total Foreign	182	22.1	1,840	54.0	3,066	76.8	3,144	78.3	2,604	72.7	1,465	59.2
U.S. and Foreign	8,247	1000	34,102	1000	39,896	1000	40,148	1000	35,831	1000	24,726	1000

TABLE 4 (concluded)

FOREIGN BORN SCIENTISTS
PER THOUSAND U.S. SCIENTISTS IN AGE GROUP

Countries	50 — 54		55 — 59		60 — 64		65 & Over & No Report		All	
	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand
Austria, Switzerland	105	6.2	92	8.1	111	15.9	91	7.8	1,077	4.8
Benelux	46	2.7	26	2.3	25	3.6	13	1.1	494	2.2
Canada	229	13.5	147	13.0	92	13.2	82	7.0	2,326	10.4
Scandinavia	14	0.8	17	1.5	15	2.2	25	2.1	310	1.4
France	15	8.9	12	1.1	17	2.4	7	0.6	231	1.0
Germany	211	12.5	174	15.4	202	29.0	123	10.5	1,865	8.3
Greece, Yugoslavia	21	1.2	12	1.1	9	1.3	3	0.3	388	1.7
Great Britain	67	4.0	58	5.1	57	8.2	46	3.9	1,505	6.7
Italy	18	1.1	11	1.0	13	1.9	6	0.5	285	1.3
Spain, Portugal	10	0.6	1	0.1	0	0.0	2	0.2	74	0.3
Japan	11	0.7	6	0.5	7	1.0	1	0.1	486	2.2
Turkey	4	0.2	4	0.4	5	0.7	4	0.3	106	0.5
All O.E.C.D.	751	44.4	560	49.5	553	79.4	403	34.4	9,147	40.9
All Other	351	20.7	252	22.3	204	29.3	159	13.6	6,387	28.5
Total Foreign	1,102	65.1	812	71.8	757	108.7	562	48.0	15,534	69.4
U.S. and Foreign	16,921	1000	11,308	1000	6,966	1000	11,707	1000	223,854	1000

Source: Same as Table 1.

Third, U.S. scientists in the past have often obtained parts of their training abroad. How has this practice developed in recent years? In what scientific disciplines is the extent of foreign training for Americans the greatest? Are these also the disciplines with the largest proportion of foreign-born?

Once the National Science Foundation has constructed the data so that it will be possible to trace persons' movements over a decade or so, it will be interesting to analyse the relative mobility of foreign as compared with that of U.S. born scientists, both within the United States and abroad.

It is perhaps not too visionary to anticipate the time when other countries will have data banks similar to that of the U.S. National Register. Then will it be possible to comprehend the full extent to which highly skilled persons are internationally mobile, how the national scientific and educational establishments of the world have become interdependent and unified into one global, more efficient system for the production and passing on of human knowledge. I venture the hypothesis that the brain drain to the United States, discussed so heatedly in recent years, will ultimately be judged to have been only an episode in the establishment of a supranational community of scientists and scholars.

A la suite du grand intérêt qu'a suscité dans l'opinion le problème du "braconnage scientifique" (brain drain), l'auteur se propose de mesurer ce que gagnent les Etats-Unis à faire ainsi appel à la main d'oeuvre hautement qualifiée. Il discute d'abord des sérieuses lacunes des données fournies par les services americains d'immigration sur les entrées des scientifiques et des ingenieurs. Ensuit, il livre les résultats d'une étude statistique. Utilisant les données du "National Register of Scientific and Technical Personnel" sur l'ensemble des scientifiques travaillant aux USA, cette étude donne une estimation du nombre de ces scientifiques qui sont nés à l'étranger; l'étude contient une analyse de leurs caractéristiques quant à l'âge, les études faites et les préferences professionnelles.

L'auteur trouve que près de 7 pour cent de tous les hommes de science americains sont d'origine étrangère; par contre, il y a 11,5 pour cent des scientifiques possédant un doctorat qui sont d'origine étrangère. Le plus grand pourcentage vient du Canada (10,4 pour mille), suivi de l'Allemagne (9,3 pour mille) et du Royaume-Uni (6,7 pour mille). Néanmoins, si l'on ajuste ces données en fonction du nombre total des natifs de chaque pays, ce sont alors les Japonais qui viennent en tête; l'on trouve ensuite les Autrichiens, les Suisses, les Beneluxiens et les Canadiens. En termes d'âge, les groupes d'âge de 20–29, 45–54, 65 et plus, pour l'année 1964, sont ceux qui relativement comprennent la plus petite proportion d'étrangers. Cela reflète vraisemblablement les décès et les études achevées à un âge avancé. Les Allemands et les Autrichiens sont fortement concentrés dans le groupe 55–64 ans; ce qui suggère que les scientifiques en provenance de ces pays peuvent avoir été victimes d'un exil forcé.

APPENDIX

TABLE I

ALL SCIENTISTS WITH PH.D., OF FOREIGN ORIGIN, BY COUNTRY OF SECONDARY EDUCATION AND SCIENTIFIC FIELD

Countries of Secondary Education	Total		Chemistry		Earth Sciences		Meteorology		Physics		Mathematics		Agricultural Sciences	
	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand
Austria, Switzerland	754	9.5	308	14.1	33	9.2	9	18.8	136	13.2	52	11.3	3	1.3
Benelux	311	3.9	91	4.2	27	7.5	3	6.3	62	6.0	23	5.0	8	3.4
Canada	1,483	18.7	444	20.4	71	19.8	11	23.0	218	21.2	89	19.3	64	27.0
Scandinavia	154	1.9	31	1.4	6	1.7	3	6.3	30	2.9	22	4.8	3	1.3
France	126	1.6	24	1.1	6	1.7	0	0.0	33	3.2	15	3.3	1	0.4
Germany	1,213	15.3	413	19.0	29	8.1	21	43.8	279	27.1	88	19.1	9	3.8
Greece, Yugoslavia	182	2.3	65	3.0	0	0.0	0	0.0	25	2.4	15	3.3	1	0.4
Great Britain	946	11.9	353	16.2	36	10.0	9	18.8	245	23.8	40	8.7	9	3.8
Italy	163	2.1	57	2.6	1	0.3	0	0.0	26	2.5	15	3.3	1	0.4
Spain, Portugal	34	0.4	8	0.3	0	0.0	0	0.0	10	1.0	3	0.7	0	0.0
Japan	346	4.4	88	4.0	9	2.5	15	31.3	88	8.6	39	8.5	2	0.8
Turkey	49	0.6	9	0.4	4	1.1	0	0.0	16	1.6	3	0.7	1	0.4
All O.E.C.D.	5,761	72.6	1,891	86.7	222	62.0	71	148.2	1,168	113.6	404	87.8	102	43.1
All Other	3,376	42.5	1,120	51.4	115	32.1	36	75.1	595	57.8	261	56.7	45	19.0
Total Foreign	9,137	115.1	3,011	138.1	337	94.2	107	223.4	1,763	171.4	665	72.8	147	62.1
All Scientists in U.S.	79,372	1000	21,789	1000	3,578	1000	479	1000	10,286	1000	4,603	1000	2,367	1000

APPENDIX

TABLE I (concluded)

ALL SCIENTISTS WITH PH.D., OF FOREIGN ORIGIN, BY COUNTRY OF SECONDARY EDUCATION AND SCIENTIFIC FIELD

Countries of Secondary Education	Biological Sciences		Psychology		Statistics		Economics		Sociology		Linguistics		All Other Fields	
	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand	No.	Per thousand
Austria, Switzerland	52	3.9	57	5.3	2	2.5	52	10.2	10	4.6	11	15.1	29	8.9
Benelux	42	3.1	12	1.1	5	6.2	18	3.5	7	3.2	3	4.1	10	3.1
Canada	270	20.2	129	11.9	21	26.1	82	16.1	29	13.3	11	15.1	44	13.5
Scandinavia	27	2.0	8	0.7	0	0.0	10	2.0	3	1.4	5	6.9	6	1.8
France	16	1.2	5	0.5	1	1.2	12	2.4	2	0.9	3	4.1	8	2.4
Germany	97	7.3	82	7.6	11	1.4	84	16.5	36	16.5	21	28.8	43	13.2
Greece, Yugoslavia	23	1.7	12	1.1	3	3.7	22	4.3	7	3.2	4	5.5	5	1.5
Great Britain	124	9.3	42	3.9	9	11.2	36	7.1	15	6.9	7	9.6	21	6.4
Italy	26	1.9	6	0.6	0	0.0	13	2.6	4	1.8	4	5.5	10	3.1
Spain, Portugal	9	0.7	1	0.1	0	0.0	0	0.0	1	0.5	2	2.7	0	0.0
Japan	66	4.9	9	0.8	4	5.0	10	2.0	3	1.4	4	5.5	9	2.8
Turkey	4	0.3	6	0.6	0	0.0	3	0.6	1	0.5	0	0.0	2	0.6
All O.E.C.D.	758	56.8	369	34.0	56	69.7	342	67.2	118	54.2	75	102.9	187	57.2
All Other	425	31.8	172	15.9	61	75.9	259	50.9	85	39.0	61	83.7	141	43.1
Total Foreign	1,181	88.4	541	49.9	117	145.5	601	118.1	203	93.2	136	186.6	328	100.3
All Scientists in U.S.	13,355	1000	10,843	1000	804	1000	5,091	1000	2,179	1000	729	1000	3,269	1000

Source: Same as Table 1.