Pakistan Journal of Applied Economics, (1988), Vol. VII No. 1, (43–58)

THE IMMIGRATION OF THIRD WORLD SCIENTISTS AND ENGINEERS TO THE UNITED STATES: Theoretical, Empirical and Policy Evaluations

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The third world brain drain problem contains elements of economic, social and political complexities. The neo-classical economic theory may, therefore, be deficient in explaining brain drain. A number of studies have focused on the effects of brain drain rather than the causes. Moreover, data availability was a problem in previous studies. This paper is concerned with a disaggregated analysis of the determinants of immigration of engineers and scientists to the U.S. from the third world countries. Attempt has been made to explain the third world professional immigration to the U.S. with a variant of Arrow-Capron model (1959). This analysis supports the view that labor market shortages explain the immigration of engineers and scientists to the U.S. An immigrant income taxation proposal may be effective in compensating the third world countries and in stopping professional immigration.

I. Introduction

The term "brain drain" refers to the migration of highly trained, skilled and talented professionals away from developing countries. These developing countries, having ambitious developing projects, need skilled manpower and suffer heavily from "brain drain". Ironically, they also incur a huge financial burden in hiring foreign professionals [Kwok and Leland, (1982)].

The third world "brain drain" problem contains elements of economic, social and political complexities. The "brain drain" is qualitatively different from general migration, because it warrants a huge amount of human capital

* The author acknowledges suggestions from two anonymous referees. Helpful comments on various drafts of this paper from Gordon V. Karels, Richard A. Defusco and Stephen E. Wilcox of the University of Nebraska-Lincoln, and research assistance provided by Munir Hassan, are also acknowledged. The usual disclaimer applies.

[Barkin, (1967)]. The neo-classical push-pull theory explains international migration as a dynamic interplay of forces that tend to "push" a person from his own country and those that tend to "pull" him back to that country. This theoretical framework relies too much on the economic disparities between developed and developing countries and ignores other important migration decisions. A lack of manpower planning in developing countries leads to an oversupply of skilled professionals. Training of these professionals in developed countries also leads to overspecialization and the consequent failure to find professionally stimulating jobs in their home countries. Moreover, rigid promotion criteria based on seniority rather than on merit encourages professionals to migrate.

Developing countries sometimes encourage emigration of their skilled manpower to relieve employment problems and to earn foreign exchange remittances. Immigration laws in many developed countries also encourage migration of skilled professionals and make it easier for foreign students to stay after completion of their degrees.

This paper is concerned with a disaggregated analysis of the determinants of immigration of engineers and scientists to the U.S. from 18 third world countries. A variant of the Arrow-Capron (1959) model of dynamic labor market shortages is used to explain the determinants of third world "brain drain". Specifically, reduced form equations are estimated for engineers and scientists for the time period 1972–1987. Explanatory variables include income, real GDP growth, graduates in the U.S., and students in each country of origin. Additional explanatory variables are foreign student enrollment in the U.S., lagged immigration and total immigration from each country.

The paper is divided into five sections. Section I gives the introduction. Section II deals with the general theoretical issues of labor migration with emphasis on the "brain-drain". Section III is concerned with an empirical analysis of third world scientists and engineers immigration into the U.S. for the time period 1972–1987. Section IV discusses policies to deal with the "brain drain" problem. The conclusion and summary of the paper is in Section V.

II. Theoretical Analysis of Brain Drain

Todaro (1969), and Harris-Todaro (1970), developed a model to explain a seemingly paradoxical situation of continued rural-urban migration in the face of rising unemployment in urban areas. The model is based on the idea that migration decisions depend upon perceptions of "expected" income. The Harris-Todaro model explains that higher expected income in the urban sector induces rural migration even in the presence of higher urban unemployment. Rural-urban migration will continue until the

expected urban income is equal to the expected rural income. This model implies that rural development will reduce rural-urban migration flows. This model may also be relevant in explaining international migration. Income differentials that exist between developing and developed countries induces emigration from third world countries. There are other factors which specially facilitate emigration of professionals.

First, absolute income difference, not relative difference, would encourage skilled workers to migrate more than unskilled workers. Given a larger absolute gain to income, the cost of moving expenses will enable a skilled worker to migrate more easily than an unskilled worker.

Second, the organized labor market for highly skilled workers creates more incentives for them to migrate than their less-skilled counterparts. Readily available information makes skilled workers more prone to migrate than unskilled workers.

Third, asymmetric market information [Kwok and Leland, (1982)], may be a cause of brain drain. Asymmetric information induces employers in developing countries to know the true productivity of a student being trained in a developed country whereas the native employers lack that information. As a result, foreign employers pay wages relevant to the true productivity of a skilled worker while native employers pay wages only equivalent to the average productivity of returning graduates. This adverse selection problem in the market for highly skilled workers may create an incentive for foreign students of higher-learning not to return home but to stay in the country of higher-learning. Chou and Yen (1985), however, found that the repatriation of Taiwanese students from the U.S. was significantly related to the U.S. unemployment rate. Their empirical analysis did not validate the claim that informational asymmetry alone can explain the brain drain provided that unemployment rate is not related to the informational advantage enjoyed by the prospective U.S. employers.

Fourth, developed nations are capital-abundant and can provide expensive research equipment to their scientists and engineers. This induces many professionals to migrate to developed countries where they will be able to apply the knowledge and training that they have acquired. In addition, bureaucratic hurdles for obtaining research funds frustrate skilled professionals in most developing countries.

Fifth, skilled professionals are exposed to the social, political and cultural ideology of developed countries. Their acquired views very often contrast with the traditional views of the societies from which they originate and they may find it difficult to live in their old society. Cosmopolitan attitudes, which they gain through education abroad, encourage skilled professionals to stay in the developed countries where they are being trained. Kao and Chao (1973) surveyed Chinese scholars in the U.S. and found

that satisfaction with the American way of life, length of residence in the U.S., U.S. income, the degree of competition in Taiwan, political freedom in the U.S., and the lack of family ties in Taiwan seemed to be the most important determinants of an individual's propensity to stay in the U.S.

Sixth, it is pointed out that foreign training involves a sort of capital gain for the trainee. By accepting a job abroad, a professional opens himself to an extended future career with more options than he would have by staying at home. The small and well informed job market, the low psychic cost of moving, the likelihood of persistent professional labor market disequalibria and the low cost of transportation relative to income tend to make professionals more responsive to a changed circumstance in a developing country, and tends to increase their mobility across borders.

Seventh, political instability in many developing countries may serve as an impetus for professionals to migrate to the developed countries where they anticipate a stable and peaceful atmosphere.

III. Empirical Analysis

a) An Empirical Overview of Foreign Students in the U.S.

It has been argued that a significant number of foreign students coming to the U.S. for higher education, tend to remain in the U.S. and eventually become immigrants. A cursory look at the U.S. data tend to support this hypothesis. Nearly 50 per cent of foreign students enrolled in American universities in 1986 came from 10 countries. Six of these countries are also ranked in the top 10 in 1955, the earliest year for which data is available. From 1980 to 1986, the enrollment of all foreign students grew at an average annual rate of 3 per cent, but when Iranian students are excluded from the data, there is a 6 per cent average annual increase [Institute of International Education, (1973–1987)].

Foreign students were more concentrated in the doctorate level science and engineering departments at doctorate-granting institutions than were U.S. citizens: 90 per cent compared to 84 per cent, in 1985. This was generally true for individual science and engineering fields, as well as for overall totals in doctorate-level departments. The proportions of both U.S. citizens and foreigners enrolled in doctorate-level departments have remained stable throughout the 1977–1985 period [see, National Science Foundation, (1986)].

Post-doctoral appointments provide opportunities for research activity for Ph.Ds. Foreigners comprised 39 per cent of the total post-doctorate employment in 1985. In some fields, however, foreign citizens made up

well over one-half of all post-doctorates. Engineering had the highest proportion of foreign post-doctorates; two of every three engineering post-doctorates in 1984 were non-U.S. citizens [National Science Foundation, (1986)].

Foreign citizens receiving doctorates in the U.S. play an important role in filling the demand for new entrants in the U.S. labor market. Of the 1980 and 1981 foreign citizens receiving science and technology doctorates, about 60 per cent of the engineers, over 50 per cent of physical and mathematical scientists, and 40 per cent of other scientists remained to work in the United States [National Science Foundation, (1986)].

b) The Model

Having analyzed the general and particular causes of the third world "brain drain", we now turn to an empirical analysis of the determinants of migration of scientists and engineers to the U.S. during the period 1972–1987. Following Green (1976), and Devoretz and Maki (1983), attempt has been made to explain U.S. immigration with a variant of the Arrow-Capron (1959) model of dynamic shortages. Our model differs from them as more economic variables are included in it. Moreover, this empirical analysis extends over a longer time period than previous studies. It is assumed that the U.S. has an excess demand ("pull" factor) for scientists and engineers, whereas the third world countries have excess supply ("push" factor) of scientists and engineers.

The U.S. demand for professional immigrants in occupation j from country i can be expressed as

$$D_{ij} = f(O_{jus} - G_{jus}, S_j, Y_{ijus}/Y_{jus}) \qquad (1)$$

where:

O_{jus} = The U.S. job openings in occupation j.
G_{jus} = The U.S. graduates in occupation j.
S_j = Substitutability of professional immigrants for similar U.S. workers.
Y_{ijus} = The U.S. income in occupation j for country i workers.
Y_{jus} = The U.S. income for occupation j.
Y_{ijus}/Y_{jus} = Relative income of professional immigrants to similar U.S. workers.

The supply of professional immigration to the U.S. from country i in occupation j can be written as

$$S_{ij} = f(G_{ij} - O_{ij}, K_{ij}, Y_{ijus}/Y_{ij}) \quad (2)$$

where:

G_{ij} = Graduates in occupation j in country i.
O_{ij} = Job opportunities in occupation j in country i.
K_{ij} = Knowledge of immigrants of country i about U.S. opportunities in occupation j.
Y_{ij} = Country i income in occupation j.

Equating $D_{ij} = S_{ij}$, we derive the following reduced form equation which will be empirically estimated in this paper.

$$I_{ijt} = f(O_{jus} - G_{jus}, S_j, Y_{jus}, G_{ij} - O_{ij}, K_{ij}, Y_{ij}) \quad (3)$$

where I_{ijt} = Number of professional immigrants in occupation j from country i in year t.

c) Data and Econometric Specification

Given data problem for the theoretical model (3), we used several proxies in this empirical analysis.

Variables	Proxies	Symbols
O_{jus}	U.S. GDP growth rate	GDPGUS
O_{ij}	Country i GDP growth rate	GDPGCOUN
Y_{jus}	U.S. income for occupation j	INCOME
Y_{ij}	Per capita income in country i	GNPCOUN
K_{ij}	Lagged professional immigration	LAGNAT, LAGENG
G_{ij}	University enrollment in area j in country i	GRADCOUN
S_j	Foreign graduate students enrolled in U.S. universities	USFGRAD
	and total number of immigrants from country i	TOTIMG
G_{jus}	Total U.S. Ph.D. graduates in area j	USGRAD

The expected signs of all these variables are presented in Table 1.

Data on immigration (ENG, NAT, LAGEND and LAGNAT) are taken from the National Science Foundation (1972–1988). These variables are measured in terms of gross migration and therefore ignore repatriation. The data also ignore transmigration, so that, for instance, a third world

citizen immigrating to the U.S. from Canada does not appear in the data. The lagged endogenous variable is assumed to capture the true direct effects of other variables and its absence tends to overstate the absolute values of other economic variables in the model [Greenwood, (1970)]. The overstatement in parameter estimates in the absence of the lagged immigra-

TABLE 1

Expected Signs of all Variables

Variables	Definition	Sign
Dependent Variables		
ENG	Engineer immigrants to U.S.	
NAT	Scientists immigrants to U.S.	
Independent Variables		
INCOME	Engineer income in U.S.	+
	Scientists income in U.S.	+
USFGRD	Foreign student enrollment in U.S.	+
GDPGUS	GDP growth in U.S.	+
GDPGCOUN	GDP growth in all countries	−
GNPCOUN	Per capita GNP of countries	−
LAGNAT	Lagged scientist immigrants	+
LAGNEG	Lagged engineer immigrants	+
USGRAD	U.S. graduates in engineering	−
	U.S. scientist graduates	−
TOTIMG	Total immigrants from all countries	+
GRADCOUN	Total university enrollment in engineering in all countries	+
	Total university enrollment in science in all countries	+

TABLE 2

Parameter Estimates for Engineer and Scientist Regressions (Full Model)

Independent Variables	Dependent Variables	
	Engineers (Eng)	Scientists (Nat)
CONSTANT	58.96 (0.98)	0.19 (0.61)
GDPGUS	4.27 (1.44)*	2.05 (2.37)*
USGRAD	−0.02 (−1.10)	−0.000040 (−2.72)*
GDPGCOUN	−1.20 (−0.88)	−0.27 (−0.80)
GRADCOUN	0.00037 (2.07)*	0.000095 (1.85)*
INCOME	−0.00021 (−0.26)	43.13 (2.42)*
GNPCOUN	−0.0064 (−1.35)*	−0.0015 (−1.07)
LAGNAT	—	0.61 (3.34)*
LAGENG	0.70 (4.79)*	—
USFGRAD	0.0046 (2.70)*	−0.13 (2.6)*
TOTIMG	0.00023 (0.36)	0.00035 (1.42)*
SSE	144.90	39.20
$\bar{R}^2$	0.79	0.81
N	288.00	288.00
F	161.37	137.53

NOTE: (1) Numbers in the parentheses are t-statistics.
(2) * = significant at 90% confidence level.
(3) The estimating equation is a linear form of equation (3) in the text.

tion variable can be attributed to fluctuations in migrations resulting from other variables when they pertain to a previous distribution of relatives and friends. The reason to take total immigration is to capture information flows from previous immigrant acquaintances.

The combined use of income variables INCOME and GNPCOUN is controversial in immigration studies because they may introduce simultaneity in the model if income responds to immigration. One view suggests that the absolute income difference between origin and destination countries determines only the direction of immigration, while others argue that destination country income is a proxy for employment growth [Greenwood (1975)]. This study includes both INCOME and GNPCOUN variables to show that professional migration responds to income differential between countries of immigration and emigration. The variable INCOME is measured with average American occupational incomes for engineers and scientists from the U.S. Statistical Abstract (1973–1988). Due to the unavailability of occupational income data for developing countries, data on per capita income has been used after converting into dollars at purchasing power parity exchange rates. Therefore, it reflects very general labor market conditions and neglects any vagaries peculiar to the professional labor market.

The growth of demand for engineers and scientists would be most closely measured by activity variables over time. In the absence of this information, GDPGUS and GDPCOUN (percentage increase in real gross domestic product from the previous year) are used which have been taken from the International Financial Statistics Yearbook 1988. Although real GDP growth rate misses differences in demand growth among professions, it does have the advantage of being less susceptible to simultaneity problems.

USGRAD is measured by the total number of U.S. graduates with doctoral degrees in engineering and natural science. This data is taken from the National Science Foundation (1986) and the U.S. Statistical Abstract (1986–1988). Similar information is not available for the developing countries. Therefore, total enrollment in each country's universities for engineering and natural science as given in the UNESCO (1973–1988) have been used as a proxy for GRADCOUN.

The data for USFGRAD is taken from the Institute for International Education (1973–1988). This variable is proxied by an aggregate which includes all nationalities for each professional course of study. Therefore, it ignores differences in substitutability by country of origin.

TABLE 3

Parameter Estimates for Engineers and Scientists Regressions
(without lagged dependent variable)

Independent Variables	Dependent Variables	
	Engineers (Eng)	Scientists (Nat)
CONSTANT	31.89 (0.28)	0.55 (1.18)
GDPGUS	7.04 (1.4)*	2.35 (1.77)*
USGRAD	−0.031 (0.69)	−0.00002 (−0.93)
GDPGCOUN	−1.76 (−0.57)	−0.31 (−0.52)
GRADCOUN	0.0015 (5.52)*	0.00032 (5.78)*
INCOME	−0.0039 (−1.82)*	29.09 (1.19)
GNPCOUN	−0.016 (−2.35)*	−0.005 (−3.25)*
USFGRAD	0.013 (5.89)*	−0.0609 (−0.82)
TOTIMG	−0.000012 (0.01)	0.00097 (4.20)*
SSE	233.16	56.24
$\bar{R}^2$	0.46	0.61
N	288.00	288.00
F	50.22	68.98

NOTE: (1) Numbers in the parentheses are t-statistics.
(2) * = significant at 90% confidence level.
(3) The estimating equation is identical to equation (3), except for the omissions of I_{ijt-1}.

d) Results

Two immigration equations were estimated, one for scientists and one for engineers, using a pooled cross-section data for 18 major developing nations and for 16 time periods. The 18 countries are Argentina, Bolivia, Brazil, Chile, China, Columbia, Greece, Hong Kong, India, Iran, Iraq, Lebanon, Mexico, Pakistan, Peru, Philippines, South Korea and Venezuela. These are all the non-European countries covered by the National Science Foundation with the exceptions of Canada and Japan. Except for Venezuela, these countries are classified as "poor" by Greenwood (1983) on the basis of per capita income below the world median.

Theory gives us no guidance as to the specific functional form of equation (3). Running an OLS regression when the relationship is not linear will result in biased parameter estimates. The most popular general functional form used for testing nonlinearity is that associated with the Box-Cox transformation, in which a variable Z is transformed to $(Z^{\lambda} - 1)/\lambda$. If all variables in a linear functional form are transformed in this way and then λ is estimated in conjunction with other parameters via a maximum likelihood technique, significance tests can be performed on λ to check for special cases. If $\lambda = 0$, the functional form is log-linear; if $\lambda = 1$, it is linear [Spitzer, (1982)]. Linearity hypothesis could not be rejected on the basis of Box-Cox test. The White (1980) test was used to correct the estimates for an unknown form of heteroskedasticity. The results reported in Table 2 support our simplified linear model (3).

Seven out of nine independent variables for scientists and five out of nine independent variables for engineers have expected signs which are significantly different from zero. The coefficients of GDP growth rates for the U.S. (GDPGUS) are significantly positive for both the scientists and engineers, indicating that aggregate income growth serves as a reasonable proxy for employment opportunities. The coefficients of U.S. graduates have expected signs for both the scientists and engineers but are significant only for the scientists. The GDP growth rate (GDPGCOUN) are insignificantly negative for emigrating nations, but here total foreign student enrollment in the U.S. (USFGRAD) are significant, perhaps indicating that substitutability is a stronger force in these fields. Foreign university enrollment (GRADCOUN) is significantly positive for both scientists and engineers as is the lagged immigration (LAGNAT, LAGENG). These results validate earlier claims that pull factors may play a greater role for third world professional immigration into the U.S. The total immigration coefficients (TOTIMG) possess expected positive signs but are significant only for scientists, implying that a greater percentage of science graduates choose to stay in the U.S.

U.S. income (INCOME) by occupation is significantly positive for scientists. This implies that the scientists migration to the U.S. depends on the income variable significantly. The higher the U.S. income for this group of professionals, the higher is the inducement for the emigration of scientists from the third world to the U.S. However, INCOME variable is insignificantly negative for engineers. This may reflect an endogeneity problem, because occupational income is highly correlated with the number of U.S. graduates in the matching academic area. The foreign occupational income proxy (GNPCOUN) variable possesses expected sign for both engineers and scientists, but is only significant for engineers. The significant coefficient of income variable for engineers may indicate a "status" symbol attached with the engineering profession in most developing countries and the fact that the engineers are relatively well-paid compared to the scientists. Therefore, the scientists are more likely to migrate to the U.S. than the engineers.

Table 3 presents the results of this immigration model without the lagged endogenous variable. This separate model is estimated in order to review the criticism that a lagged endogenous variable model suffers from spurious correlation and is merely an indirect test of the impact of economic variables in previous periods. This regression shows that our previous results do not suffer seriously from spurious correlation, simply reflecting the impact of economic variables in previous periods. With the revision the model still maintains its basic properties. Most of the variables retain their expected signs, although the significance of some variables has changed.

The model validates the thesis that dynamic labor market shortages explain the flow of professional immigrants from the third world to the U.S. It also supports Sen's (1973) conclusion that U.S. education for foreigners has an important impact on immigration.

IV. Policy Implications

Public policy makers differ in their views of the brain drain problem depending on the economic analysis they use. One view advocates that professionals will migrate from low-productivity, low-wage developing countries to high-productivity, high-wage developed countries. Accordingly, marginal productivity of labor increases in developing countries and professionals are optimally redistributed internationally. Therefore, the international community benefits as a whole from cross-border mobility of such skilled labor.

Critics of this approach contend that the exit of professionals from a country significantly hampers its development. In the long run, the

emigration of manpower erodes the competitive edge of developing nations and make them more dependent on developed nations. Therefore, direct curbs on the right to leave are a proper and effective means for dealing with this problem.

Many economists sympathize with both views and cite the moral dilemma of restricting the freedom of a number of people for the sake of the nation. If it is agreed that economic growth and development of developing nations suffer from the "brain drain", a policy of brain drain restriction can be formulated.

The empirical results clearly show that income differential and employment opportunities between developing and developed countries are significant determinants of professional migration. In the long-run, cooperative steps can be taken to narrow the income gap between developed and developing nations. To reduce the emigration of professionals, governments of developing countries should undertake comprehensive manpower planning. Prohibiting emigration will bring little benefit to nations that cannot offer suitable jobs to those kept at home. Their talents will still be lost. Likewise there is no "drain" if they leave, since they contribute little or nothing to development by remaining there. The developing countries should find a balance between training and employment, preferably through positive measures that increase job openings for professionals. Developed nations could provide training in technology for foreign students applicable to the development needs of their countries. When a country reaches a point where it can afford its expatriates, most of them are likely to return of their own accord, given that ties with family, culture, and homeland are not easily broken. The recent repatriation of Korean professionals attests to this phenomenon.

The empirical results also show that foreign training is an important factor for professionals not returning home because they can find suitable jobs in the U.S. The U.S. government can cooperate with the governments of developing countries to ensure that the foreign students return home after they complete their studies in the U.S. The U.S. however, has recently passed a new Immigration Bill that will make it easier for an aspiring foreign student to stay in the U.S. and become an immigrant.

The government of developing countries could undertake specific steps to halt the brain drain caused by students. First, government policy should aim at pooling information about the nature and quality of foreign educational institutions and make them available to students aspiring to go abroad. This will narrow the "information gap" and help third world employers design an effective compensation scheme that reflects true productivity of professionals returning home. Second, government should include a "return bond" to the students going overseas with government

scholarships. A number of developing countries require that students must return home upon completion of studies or otherwise incur financial losses. However, many countries do not strictly enforce this policy. Third, the government can offer subsidies to students who are considering to return home. These subsidies may include transportation cost to the students and their families. Fourth, the government can offer lucrative jobs along with other facilities to the professionals who are considering to return home. Fifth, government of developing countries can establish prestigious institutions offering degrees in science and technology substitutable to foreign degrees.

A number of scholars argue that the "brain drain" dilemma will persist and the developed countries should compensate the developing countries for their loss of human capital through economic and technical aid. A specific policy could be to levy a surtax on the immigrant skilled manpower in the developed countries and remit the collected revenues back to the developing countries [Bhagwati, (1976); Bhagwati and Dellalfar, (1973)]. This empirical analysis indicates a significant positive correlation between the U.S. income (INCOME) and scientists immigration to the U.S. An immigrant income tax proposal may be effective in compensating the third world countries and altering the flow of scientist immigration to the U.S. The insignificance of the U.S. income variable (INCOME) for engineer immigrants may be attributable to its endogenous nature, and therefore it is premature to conclude that an immigrant income tax proposal would be ineffective in altering the flow of engineer immigrants to the U.S. Legal experts contend that it would be very difficult to implement this policy in the U.S. because it would raise definitional problems, human rights questions, and other practical issues.

V. Conclusion

A number of conclusions can be derived from this analysis of third world "brain drain" problem.

First, the brain drain problem does exist in most developing countries. The social costs of brain drain far outweigh the private benefits, because the migrating professionals are educated mostly by public money.

Second, the empirical model validates the hypothesis that labor market shortages in the U.S. explain the engineers and scientists immigration to the U.S. The "pull" factors are more important than the "push" factors in the determination of engineers and scientists migration.

Third, despite the legal and administrative problems of an immigrant income tax proposal, this empirical analysis indicates that such a policy

may be effective in compensating the third world countries and altering the scientists immigration to the U.S.

Fourth, the developing countries cannot alone mitigate the "brain drain" problem without the help of the developed nations. The developed nations derive immediate as well as long term benefits from professional immigration. The developed countries can loosen restrictions on the movement of semi-skilled people to partly reimburse the developing countries for the benefits they derive from immigration of professionals. The developed nations can also consider financial compensation to developing countries for their losses from the "brain drain".

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