Discussion Paper

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH
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On-the-Job Training as a Cause of Brain Drain

by

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I. Introduction

Brain drain has long been a concern of development economists. Traditional theory views brain drain as a manifestation of labor mobility, which responds to the difference in the marginal productivity of skilled labor in different locations (Grubel and Scott[1966], Johnson[1972]). The cause of the productivity difference is thought to be the difference in the stock of physical capital which complements skilled labor in the production process. The most prevalent form of brain drain, however, is not outright migration of skilled labor, but rather the retention of foreign students who fail to return home following the completion of advanced education in developed countries (Grubel and Scott [1966]). Traditional theory does not interpret this phenomenon very well.

Kwok and Leland (1982) provides an alternative explanation of brain drain, built upon the assumption of information asymmetry. They argue that the employers in the country where a foreign student receives terminal education have an informational advantage in judging the student's capability over the employers in the country where the student has originated. The informational barrier forces the potential employers of the home country to reward the returning students in accord with their average productivity. This sets in work a process of "adverse selection," which drives away the premier students and takes home only the mediocre ones. This line of interpretation, though possible theoretically, is implausible in the real world. An information barrier may exist temporarily, but should not persist once the employers in the home country have some recruitment experience with returning foreign-educated students. The theory also has difficulty explaining why an information barrier is more serious in some professions than others and in relating this difference to the severity of the brain drain itself.

This paper presents a simple model of brain drain, built upon the traditional argument of marginal productivity difference and appended by investment-in-human-capital theory. We argue that capital stock not only affects the marginal productivity of skilled labor but also influences the efficacy of on-the-job training, which is an important conduit for human capital accumulation. In fact, in many fields, on-the-job training is essential in attaining or perfecting the skills needed in those professions. As argued by Mincer(1962), graduation from schools usually signifies the end of a general educational stage and the beginning of a more specialized process of acquisition of occupational skills. Our model shows that in the fields where on-the-job training is more important to specialized skills, the returning rate of overseas-educated students is lower. The model is consistent with the brain drain patten of Taiwanese students who received post-secondary education in Japan.

II. Model

A student from a developing country decides whether to return to his home country to work after completing his education in a developed country (hereafter denoted as foreign country) on the basis of the present value of his future income streams. Simply put, a student will remain in the foreign country if and only if

$$v^* \geq v + c \qquad (1)$$

where v^* is the present value of income streams expected from working in the foreign country, and v is its counterpart in the home country, c is the compensation variation which measures the money-equivalent of disutility arising from living in a foreign country. We assume c to be positive, otherwise the model degenerates into a trivial case where all students stay in the foreign country after graduation.

The student expects the wage rate to be w^* in the foreign country and w in the home country; both are constant throughout his working life, and $w^* > w$. The constant wage assumption will be relaxed later on. Then, equation (1) may be rewritten as

$$\int_0^T w^* e^{-rt} dt \geq \int_0^T w e^{-rt} dt + c$$

$$\text{or} \quad (w^* - w)\left(\frac{1 - e^{-rT}}{r}\right) \geq c \qquad (2)$$

where r is the discount rate and T is the time span of the student's working career. The student joins the labor force at time 0 when he graduates and retires at time T. Equation (2) implies that, other things being equal, a younger graduate has a greater likelihood to stay in the foreign country than an older one, since the former has a longer working career which magnifies the present value of wage differentials.

Assume that the marginal productivity of the skills possessed by the student depends positively on the stock of capital existing in the industry. For instance, the marginal productivity of a physician who specializes in surgery depends on the sophistication of the medical facilities that he has access to. A computer software specialist derives his marginal productivity from the availability of computer hardwares as well as from the knowledgeable people who value the software program that he designs. Recent papers by Becker, Murphy and Tamura(1990), Azariadis and Drazen(1990), and Stokey(1991) have emphasized the positive externalities of human capital in the sense that the rate of return to human capital increases as the social stock of human capital increases. Following this line of argument, we shall interpret our capital to encompass both physical and human capital. The social stock of capital, therefore, determines the marginal productivity of individual skills, i.e.,

$$w^* = \alpha K^* S$$
$$w = \alpha K S \qquad (3)$$

where $K^*(K)$ is the stock of capital in the foreign (home) country; S is a positive number indicating the level of skills possessed by the student; α is a positive parameter whose value varies from profession to profession.

Substituting equation (3) into (2) yields the following:

$$\alpha(K^*-K)S\left(\frac{1-e^{-rT}}{r}\right) \geq c \qquad (4)$$

The skill level which establishes equality in equation (4) can be found as

$$\bar{S} = \frac{c}{\alpha(K^*-K)}\left(\frac{r}{1-e^{-rT}}\right) \qquad (5)$$

When the level of skills possessed by a student is less than the critical level expressed in equation (5), the student will return to the home country to work; otherwise, he will stay in the foreign country. The result is similar to Kwok-Leland's in that only the inferior students return while the superior ones stay. We have, however, assumed that employers in both foreign and home countries possess perfect knowledge of the student's marginal productivity.

Let the cumulative distribution function of S be F(S), and further assume the working life, T, to be identical for all students, then the probability that a student returns to the home country is F(S), and the probability of his staying is P=1-F(S). It can easily be seen that the probability of staying is affected by the capital stock. That is,

$$\frac{\partial P}{\partial K^*} = \left(\frac{rc}{(1-e^{-rT})(K^*-K)^2}\right) f(S) \geq 0$$

$$\frac{\partial P}{\partial K} = \left(\frac{-rc}{(1-e^{-rT})(K^*-K)^2}\right) f(S) \leq 0 \qquad (6)$$

Where f(S) is the probability density function (p.d.f.) associated with F(S). In other words, an increase in the social stock of capital in the foreign country raises the probability that a student stays after graduation, while a similar increase in the home country lowers that probability. Hence, additions to capital stock, physical or human, by a developing country attract more of its native students to return with an improvement in the average quality of returnees. Autonomous capital accumulation, therefore, sets in process a virtuous cycle whereby the degree of brain drain is lessened and the growth in human capital stock is accelerated.

The dependency of the marginal productivity of skills on the stock of capital, although a plausible cause of brain drain, is inadequate in answering the question of why retention of foreign students in advanced countries is the most prevalent form of brain drain. At this juncture, we introduce the assertion that the efficacy of on-the-job training is also affected by the existing stock of capital, i.e., the return to training depends positively on the social stock of capital, including physical facilities and human knowledge. This reinforces the effect of capital stock on the earning potential of a foreign-educated student. If there is complementarity between school education and on-the-job training, it is conceivable that the degree of complementarity is higher when education and training take place in the same country than in separate countries. Hence, a student who receives foreign education will benefit more from on-the-job training provided by foreign industries than a student who receives indigenous education and migrates abroad to work[1]. This may explain why foreign-educated students have a stronger incentive to migrate than the domestic-educated.

Let the rate of human capital accumulation through on-the-job training decrease over time and the maximum amount of accumulation depend on the social stock of capital. We may write the skill level of a foreign-educated student as

$$S_t^* = S_0 + A^*(1-e^{-gt})$$
$$S_t = S_0 + A(1-e^{-gt}) \qquad (7)$$

where S_0 is the level of skills possessed by the student at the end of school education; $S_t^*(S_t)$ is the skill level at time t if he enters the labor market in the foreign (home) country; $A^*(A)$ is the maximum amount of skills he may accumulate through on-the-job training in the foreign (home) country; g is the negative rate of growth in the speed of accumulation.

Let the maximum accumulation be determined by the following formula:

$$A^* = b + \sigma K^*$$
$$A = b + \sigma K \qquad b>0,\ \sigma>0 \qquad (8)$$

[1]An alternative explanation is that technology is location specific and education is geared toward the local technology. In this case, the degree of brain drain depends on the degree of technological difference between the home country and the foreign country. To the extent that the effect of technology on the productivity of human skill is captured by capital, the following analysis still applies.

where b stands for the part of skills which may be achieved by individual effort irrespective of social stock of capital, and $\sigma K^*(\sigma K)$ stands for the part of skills which may be acquired only via working with the existing capital stock. The relative weight of the capital-dependent component, $\sigma K(\sigma K^*)$, to non-capital-dependent component, b, varies from profession to profession. For example, a mathematician may excel himself largely through his own dedication to the field of mathematics, while a nuclear engineer can hardly improve his professional skills without some access to nuclear facilities.

Substituting equations (3), (7) and (8) into equation (1), we obtain the probability of a foreign-educated student remaining abroad after graduation:

$$P = 1 - F(\bar{S}_0) = 1 - F\left(\frac{cr}{\alpha(K^*-K)(1-e^{-rT})} - D[b+\sigma(K^*+K)]\right)$$

where

$$D = 1 - \frac{r[1-e^{-(g+r)T}]}{(g+r)(1-e^{-rT})} > 0 \qquad (9)$$

Equation (9) indicates a probability which is higher than that embodied in equation (5) as long as b and σ are positive. In essence, accumulation of human capital via on-the-job training, whether capital dependent or not, raises the opportunity cost of returning home. This is so because any increment of human capital via training receives a higher payoff in the capital abundant country due to greater marginal productivity. Equation (9) also indicates that p increases with σ. That is, other things being equal, the degree of brain drain is more serious in the professions where on-the-job training is more capital dependent. Furthermore, capital-dependent training also makes the probability of brain drain more sensitive to foreign capital stock and less sensitive to domestic capital stock, compared to the case in which training is capital independent. This can be seen from the following:

$$\frac{\partial P}{\partial K^*} = \left[\frac{rc}{\alpha(1-e^{-rT})(K^*-K)^2} + \sigma D\right] f(S)$$

$$\frac{\partial P}{\partial K} = \left[- \frac{rc}{\alpha(1-e^{-rT})(K^*-K)^2} + \sigma D\right] f(S) \qquad (10)$$

We can show that $P/ K^*>0$ and $P/ K<0$ [see Appendix], which is qualitatively the same as equation (6). Equation (10), however, shows that given p.d.f., the extent to which domestic capital accumulation may improve the chance that a native student returns after receiving foreign education is weakened by the existence of capital-dependent, on-the-job training. The higher σ is, the smaller $\| P/ K \|$ is, provided that home capital remains at a lower level than the foreign capital. Note that given an infinitesimal change in the stock of foreign and of home capital, the probability of brain drain changes by

$$dP = \left[\frac{rc}{\alpha(1-e^{-eT})(K^*-K)^2} (dK^*-dK) + \sigma D(dK^*+dK)\right] f(S) \qquad (11)$$

Therefore, given p.d.f., the sensitivity of the probability of staying with respect to the capital-stock differentials is, attenuated by the presence of the on-the-job training effect that is capital-dependent. That is, starting with the same probability of brain drain (hence the same f(S),) it is more difficult to reduce the degree of brain drain by boosting domestic capital for the professions where on-the-job training is more capital dependent. Note, however, that the professions where on-the-job training is more capital dependent (a higher σ) also start with a higher degree of brain drain (a higher p) at any given capital gap. If a high σ profession is also characterized by a large p.d.f. at the initial point of brain drain, it can be more sensitive to domestic capital formation than the low σ profession. This happens because the change in capital differential affects the decision of a large fraction of students who possess the marginal skill in the high σ profession. Whether and where this occurs depends on the distribution of skills.[2]

III. Empirical Study

To verify the importance of on-the-job training on brain drain and its implications for occupational difference, we will study the repatriation pattern of Taiwanese students who received education in Japan. The sample is drawn from the data file of the Yoneyama Rotary Club of Japan and contains information on Taiwanese students who received Rotary Club Scholarships while being educated in Japan and who graduated between 1962 and 1988. The sample includes 776 students, of which 638 are male, and 138 female. The data file indicates the highest degree received by each student, including a bachelor degree, a master degree, or a Ph.D.[3].Since scholarship recipients are normally premier students, the degree of brain drain measured from their repatriation rate is higher than the average Taiwanese students who have been educated in Japan, according to the model.

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[2]The probability of brain drain approaches zero for all professions when the capital stock differential approaches zero. Therefore, in the process where the domestic capital stock catches up with the foreign capital stock, the probability of brain drain should decrease more rapidly (in absolute terms) in a certain range for a higher σ profession which starts with a higher p. But that range may not be empirically relevant. For example, if skill S is uniformly distributed between [a,b] where $b>a>0$, then the effect of domestic capital formation is always weaker for higher σ professions as long as the critical skill level, S, remains in [a,b] for all professions.

[3]In Japan, a Ph.D. degree in the humanities is not conferred at the end of a student's education in school. Instead, the degree is often granted only when a person's academic achievement justifies such an honor, which often comes in the later stage of his career. Therefore, humanity majors who have completed all the post-msaters' degree work and have graduated from schools are considered as Ph.D.s in this study.

The students in our sample majored in various disciplines, which can be chiefly divided into the humanities, law, sciences, medicine, engineering, agriculture, business and a catch-all category, named "others". The "others" category includes the fields that have a smaller concentration of students, such as the arts and education. Since data on the actual stock of capital (including human capital) for each profession are hard to come by, we will make an inter-professional comparison based on apriori knowledge about the nature of these disciplines. If we are to dichotomize these disciplines, the professional skills pertinent to medicine, engineering and business are more dependent on capital stock than the rest in exploiting human productivity as well as in effectuating on-the-job training[4]. We may refer to these fields as capital-dependent professions, and the rest as non-capital-dependent professions[5]. Note that the dividing line is drawn in accord with a relative, not an absolute, measure.

We first list the repatriation pattern of all disciplines in Table 1. It can be seen that the fields of medicine, engineering, and business sufer a higher degree of brain drain in that a higher percentage of graduates fail to return home. In medicine, 61.9% of graduates stay in Japan after completing their education, which includes internships. At the lower end, in the humanities, only 21.4% stay after graduation. The difference is

[4]The extent to which capital affects productivity (α) and on-the-job training (σ) may not be perfectly correlated, but they tend to be highly correlated. We implicitly assume that the degree of correlation is high enough so that the ranking of α is consistent with that of σ. Thus, the productivity effect and the training effect always move in the same direction in altering the probability of brain drain.

[5]Whether the sciences discipline should be classified as capital dependent or not is subject to debate. Sciences majors who graduated with an advanced degree often enter the teaching and research professions. The teaching profession is relatively capital free, while the research profession can be very capital dependent. On the other hand, sciences majors graduated with a baccalaureate degree tend to enter diverse professions. Detailed information on the profession choice is lacking and casual observations suggest that many choose a teaching career. We therefore classify the sciences discipline into the non-capital dependent category. The difference in brain drain resulting from the degree earned will be taken into account in the following regression analysis.

more than apparent. To explain this pattern in terms of information asymmetry, we must assert that medical skills are more difficult to evaluate than competence in the humanities. This seems to be contradictory to the common notion. Based on this dichotomy, we may proceed to putting medicine, engineering and business disciplines in the capital-dependent category which gives an overall stay rate of 48.7%. In comparison, the non-capital-dependent category has a combined stay rate of 25.6%. The null hypothesis that the two broad categories exhibit no difference in repatriation pattern yields a Pearson's X^2 statistic (with Yates correction) of 39.5, indicating that the hypothesis can be rejected at the 1% significance level. We may then conclude that the capital-dependent disciplines exhibit a higher degree of brain drain.

To see how the repatriation pattern varies over time, we divide the sample into two subperiods, using 1980 as the line of separation, and list the results in Table 2. We choose 1980 because it cuts the samples into two subperiods roughly equal in size and because in the 1980s Taiwan was widely acknowledged as a newly industrialized country, which signifies a capital capacity comparable to that of an industrialized society. Table 3 shows that there was little change in the student's stay rate after 1980 among the capital-dependent disciplines as the percentage decreases only slightly from 51.4% to 46.4%. In contrast, the stay rate among the non-capital-dependent disciplines drops significantly from 35.2% to 16.2%. This suggests that in the relevant range of skill distribution, the more the efficacy of on-the-job training depends on capital stock, the less effective the home country's capital accumulation is on the reduction of brain drain.

In fact, testing the null-hypothesis that there is no change in the repatriation pattern of the two subperiods, the Pearson x^2 statistic is 0.99 for the capital-dependent professions and 12.8 for the non-capital-dependent ones. The former fails to reject the hypothesis, while the latter does so at the 1% significance level.

In addition to time and discipline, there are other conceivable factors which may affect a student's choice between returning and staying, such as sex, degree, etc..[6] We, therefore, formulate a logit model to formally capture the effect of such variables on the decision of individual students regarding whether to return home:

$$\log\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 TIME + \beta_2 BACH + \beta_3 PHD + \beta_4 SEX + \beta_5 PROF \qquad (12)$$

where P is the probability that a student stays in Japan to work after graduation. The explanatory variables are, respectively,

TIME = time of graduation; March 1962, which is the earliest graduation date in the sample, is given the value of 0; add 1 for each month beyond this date.

BACH = dummy variable for educational level; 1 for the students whose highest degree earned in Japan is a bachelor, 0 otherwise.

PHD = dummy variable for educational level; 1 for the students whose highest degree earned in Japan is a Ph.D. or its equivalent, 0 otherwise.

SEX = dummy variable for sex; 1 for male, 0 for female.

PROF = dummy variable for professions; 1 for the capital-dependent disciplines, i.e., medicine, engineering and business, 0 otherwise.

Note that the model sets a master degree as the reference point for educational level; the dummy variables BACH and PHD are intended to capture the effect on brain drain of both lower and higher educational statuses respectively. The regression result is reported in Table 3 under the heading of "All."

It can be seen that TIME, BACH, and PROF exert a significant impact on the probability of brain drain. TIME has a negative parameter estimate, indicating that as time passes, the probability that a graduate would stay in Japan to work decreases. This implies that Taiwan has steadily reduced the gap of the social stock of capital between

[6]The age variable is theoretically important but unfortunately unavailable from the data set.

itself and Japan. BACH has a positive parameter estimate, indicating that college graduates have a higher tendency to stay than the graduates of the master programs. Meanwhile, PHD produces an insignificant estimate, indicating that Ph.D.'s do not differ from those with master degrees in their stay-return pattern. PROF has a positive parameter estimate, signifying that capital-dependent professions are plagued by a higher degree of brain drain. Finally, there is no gender gap for the brain drain as SEX turns out an insignificant parameter estimate.

The only not-so-straightforward result is that college graduates exhibit a higher stay rate than those who received advanced degrees. Therefore, three explanations are in order. First, college graduates are younger and expect a longer working life; hence, they are more sensitive to wage differentials. Second, to the extent that on-the-job training is a substitute for advanced education, college graduates may expect more intensive on-the-job training which amplifies the difference in income streams caused by capital-stock differentials. Finally, those who receive college education in Japan are likely to have better command of the Japanese language than those who enter Japan at an older age to receive advanced education. As shown by McManus(1985) and Kossoudji (1988), superior language ability improves an immigrant's earning potential.

To see how the pattern of brain drain differs between professional groups, we apply the same logit model to the capital-dependent and non-capital-dependent professions separately. The results are reported in the last two columns of Table 3. It can be seen that all parameter estimates show identical signs. Again, TIME and BACH are the only variables which reveal statistical significance. The parameter estimate for TIME is notably different between the two groups.[7] From the logit model, we may derive the rate at which the probability of brain drain declines over time, i.e.,

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[7]The statistical significance of the difference is easily verified by the t-statistic test.

$$\frac{\partial P}{\partial (TIME)} = P(1-P)\beta_1$$

Measuring the above relation at March, 1963 for a male graduate with a master degree yields the following estimates:

$$\frac{\partial P}{\partial (TIME)} = -0.000645 \text{ for capital-dependent professions,}$$
$$= -0.00219 \text{ for non-capital-dependent professions.}$$

That is, the probability by which a Taiwanese student would stay in Japan after graduation decreases by 0.0645% each month if he majors in medicine, engineering, or business, and by 0.219% each month if he majors in other fields. The difference is evident.

IV. Conclusion

This paper presents a simple model based on the assertion that the efficacy of on-the-job training, as well as the productivity of skills, depends on the social stock of capital. It shows that as the degree of dependency of on-the-job training upon capital stock increases, the problem of brain drain becomes more severe and more difficult to correct. The model may explain why the failure for foreign-educated students to repatriate is a more prevalent form of brain drain than outright migration of skilled labor. It is consistent with the repatriation pattern of Taiwanese students who received post-secondary education in Japan.

Table 1
Repatriation Pattern, 1962-1988

Discipline	Number of Students	Those who Returned	Those who Stayed	Stay Rate (%)
Medicine	160	61	99	61.9
Engineering	175	100	75	42.9
Business	148	87	61	41.2
Law	32	20	12	37.5
Sciences	49	34	15	30.6
Humanities	84	66	18	21.4
Others	38	31	7	18.4
Total	776	446	310	31.9

Table 2

Repatriation Pattern in Pre- and Post-1980 Periods

Periods	Number of Students	Those who Stayed	Those who Returned	Stay Rate (%)
Capital-Dependent Professions				
1962-1979	218	106	112	51.4
1980-1988	265	142	123	46.4
Total	483	248	235	48.7
Non-Capital-Dependent Professions				
1962-1979	145	94	51	35.2
1980-1988	148	124	24	16.2
Total	293	218	75	25.6

Table 3
Logit Model for Separate Professional Groups

Explanatory Variables	All	Capital-Dependent Professions	Non-Capital-Dependent Professions
CONSTANT	-0.2397 (0.3406)	0.3076 (0.4269)	0.5907 (0.5721)
TIME	-0.0047* (0.0012)	-0.0026* (0.0014)	-0.0088* (0.0021)
BACH	1.4525* (0.2505)	1.2715* (0.2792)	2.1033* (0.5559)
PHD	0.2506 (0.1789)	0.2463 (0.2118)	0.1427 (0.3444)
SEX	-0.1434 (0.2184)	-0.1359 (0.2776)	-0.2091 (0.3684)
PROF	0.9670* (0.1705)		
log-likelihood Function value	-476.28	-322.21	-150.47
X^2 value	91.62	24.80	32.40

Note: Numbers in parentheses are standard errors. * indicates that the asymptotic-t value is significant at the 5% level.

Appendix

Since $0<P<1$, from equation (9), $\overline{S}_0>0$, or

$$-\frac{rc}{\alpha(1-e^{-rT})(K^*-K)} + D[b+\sigma(K^*+K)]<0$$

Divide both sides by K^*-K, which is positive by assumption:

$$-\frac{rc}{\alpha(1-e^{-rT})(K^*-K)^2} + \sigma D + \frac{D(b+2\sigma K)}{K^*-K} <0$$

Since $\frac{D(b+2\sigma K)}{K^*-K} > 0$, the following must hold:

$$-\frac{rc}{\alpha(1-e^{-rT})(K^*-K)} + \sigma D <0$$

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