Heterogeneous Talent and Optimal Emigration[1]

A Contribution to the New Economics of the Brain Drain

Nguyen Duc Thanh

National Graduate Institute for Policy Studies (GRIPS), Tokyo

Vietnam Development Forum (VDF) Tokyo

Email: d0311@stu.grips.ac.jp

September 30, 2004

Abstract

This paper is a contribution to a new line of theory arguing that a certain outflow of human capital (brain drain) is not always a bad thing to the source country. First, it enriches the methodology by solving the problem with assumption on workers' heterogeneous talent and shows that the distribution of talent is important. Second, in contrast to the previous literature, this paper shows that positive effect of the outflows may never take place under some certain conditions. Third, if there is a positive effect, there exist conditions in emigration constraints that maximize the gain from brain drain - or the *"optimal brain drain"* conditions. Relevant policies on emigration for the source country are then suggested.

Keywords: Migration, Brain drain, Human capital formation, Small-open economy

---

[1] Prepared for the *Conference on Growth, Development, and Macroeconomic Policy*, December 17-18, 2004, Indian Statistical Institute, Delhi, India. I am grateful to Professor Kenichi Ohno (GRIPS), Associate Professor Futoshi Yamauchi (IFPRI and FASID), and seminar participants at GRIPS in Tokyo for their valuable comments and helpful suggestions.

1. Introduction

The term “brain drain” was popularized after WW II when there was a huge number of leading scientists immigrating to United State from Western Europe, Canada and Soviet Union (Rapoport 2002). However, the causes and consequences of brain drain led to debates and resolutions in the United Nations only as early as 1967, concerning the argument that the poor countries lost their most talented people to the rich countries (Lowell 2002). During the 1970s, many economists paid attention to the issue, creating the first wave of “brain drain” economics. Notably Jagdish Bhagwati, among others, may be the most influencing figure in the debates. Economists during the period shared, more or less, a consensus that brain drain is a zero-sum game, in which the rich nations gain on the loss of the poor nations. (Bhagwati and Hamada 1974, Bhagwati 1976, Bhagwati and Partington 1976, Hamada 1977, Bhagwati 1979a, 1979b, and later Kowk and Leland 1982, Miyagiwa 1991). This first wave seemed to fade away with the decline of the “first generation” of development economics in the late 1970s[2]. It must wait for almost two decades to see the second wave to take place, following the raise of “new” growth paradigm, in which human capital was realized as an important engine of economic growth.

Mountford (1997) for the first time argues that brain drain is not always a “curse” to poor countries, if not an effective way to escape from the “poverty trap”. His argument is that people in a poor country may have stronger motivation to get more skills if they see some probability of emigrating to a rich country, where they can earn more with the same level of human capital. This line of thinking has been developed theoretically (Vidal 1998, Stark et al. 1997, Dos Santos and Postel-Viney 2003), and empirically (Beine et al. 2001, 2003). As a result, a new generation of brain drain policy is introduced (Stark et al 1998, Stark and Wang 2002, Dos Santos and Postel-Viney 2003, Stark 2004) and gradually considered (Drinkwater et al. 2002, Lowell 2002, Lowell and Findley 2002).

This paper is a contribution to this line of theory. It develops a model reconfirming that brain drain is not always a bad thing to the source country. But it differs from previous literature in some aspects. First, the paper loosens the homogeneous worker assumption and shows that heterogeneous talent is an important determinant of brain gain or brain drain. Second, in contrast to the previous studies, this paper shows that positive effect of brain drain is not inevitable: under some conditions, this effect never occurs. Third, if there is positive effect, there exist conditions of emigration constraints to maximize the gain from brain drain - the optimal brain drain conditions.

[2] Barro and Sala-i-Martin (2004: 16-21) provide a good brief review of phases in development of growth theory.

The next sections present three models. The first is a general model, which setups basic assumptions and points out a general approach to solve the problem. The second is a baseline model applied to the case of general emigration. The third extends the applications to a more realistic case of brain drain. The final section is the conclusion.

2. A General Model

2.1. Assumptions

Workers' talent (τ) ***:***

Consider a small economy including N workers with different degrees of talent. Following Lucas (1988), assume that a worker's talent τ_i follows a given probability density function (pdf), $f(\tau)$. This means, the probability of a worker with degree of talent τ_i is $f(\tau_i)$, or the number of people with talent τ_i is: $n_i = Nf(\tau_i)$. The following conditions hold: $\lim_{\tau \to 0} f(\tau) = 0$ and $\lim_{\tau \to \infty} f(\tau) = 0$ (Figure 1).

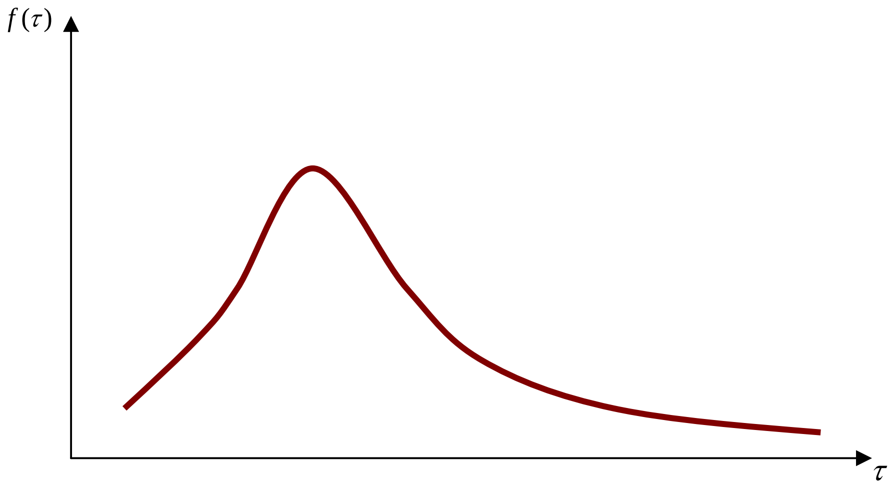

Figure 1. Probability density function of a worker's talent

As a continuous pdf, this condition holds:
$$\int_0^\infty f(\tau)d\tau = 1 \qquad (1)$$

Cost of education (c) and individual human capital formation (h):

Workers work and at the same time choose to invest on their own human capital. The human capital investment expenditure is c_i. If one invests c_i, she will accumulate a stock of human capital h_i:

$$h_i = h_i(c_i, \tau_i) . \qquad (2)$$

$h(c,\tau)$ may be called the human capital formation function. This function shows that the individual human capital accumulated depends on the worker's talent and her human investment expenditure. In principle, she can receive more education from school or more skills from leaning-by-doing or from any source, but these activities are costly in terms of real resource, which are counted in c_i.

In general, *h* holds the following properties:

$$\frac{\partial h}{\partial c} > 0; \qquad \frac{\partial^2 h}{\partial c^2} < 0 ; \qquad \frac{\partial h}{\partial \tau} > 0 \qquad (3)$$

From these properties, one can obtain the substitution rate of investment expenditure and talent:

$$\frac{dc}{d\tau} = -\frac{\frac{\partial h}{\partial \tau}}{\frac{\partial h}{\partial c}} < 0; \qquad (4)$$

This implies that to attain a same amount of human capital, the more talented the worker is, the less real resource she has to sacrifice.

Worker's total income (TU):

The compensation for worker's labor is assumed equal to her level of human capital stock: $U_i = h_i$. That means, her life income is:

$$TU_i = h_0 + [-c_i + h_i(c_i, \tau_i)]. \qquad (5)$$

Where h_0 is the worker's initial human capital endowment.

Probability of emigration (π):

Each worker has chance to emigrate to another country where the marginal human capital product is higher. Therefore, at any level of human capital stock, the successfully emigrating worker will receive an income ω times higher than the same worker working domestically, or:

$$U_{i(migrate)} = \omega U_i \quad (\omega > 1). \qquad (6)$$

Suppose the probability of success is $\pi = \pi(h)$. π can be an increasing, decreasing, or constant function of *h*, depending on migration policies or other current situations.

Objective function:

It is assumed that each worker decides how much real resource to invest in her human capital to maximize her expected life income. Or:

$$\underset{(c)}{Max}(TU_i) = h_0 - c_i + E(U_i)\,. \qquad (7)$$

2.2. General Solution

Our central concern is the domestic aggregate human capital formation (H), which has been widely realized as an important source of productivity and economic growth. The model's solution includes some steps. First, we calculate H in cases with and without emigration. Second, we compare them and examine how the difference between them depends on the model's parameters.

Human capital formation without emigration (H_0)***:***

In the case of closed economy, having solved the maximization problem of her own, the worker at given talent τ_i will choose to invest $c_{0i}^*(\tau_i)$ in her human capital, therefore she possesses a level $h_{0i}^*(\tau_i)$ of human capital. Thus, total human capital stock of the economy H_0 is the sum of all $h_{0i}^*(\tau_i)$. Since (τ_i) is a continuous variable:

$$\mathrm{H}_0 = \int_0^\infty [h_0 + h_0^*(\tau)] N \cdot f(\tau) d\tau$$

$$\Rightarrow \mathrm{H}_0 = \mathrm{H}_0(h_0, \bar{f}) \qquad (8)$$

where $\bar{f}$ is parameter vector of the pdf of talent.

Human capital formation with emigration (H_E)***:***

When emigration is possible, workers will consider whether to invest more in their own human capital to emigrate. However, due to a set of emigration constraints (denoted by Ψ), there may be not all workers willing to emigrate. Only the workers whose talent belongs to a certain range $\mathrm{T}^*(\omega, h_0, \bar{f}, \Psi)$ have incentive to go abroad (with some probability of success). These workers will invest more in education in hope of emigration. Those whose talent $\tau \notin \mathrm{T}^*(\omega, h_0, \bar{f}, \Psi)$ decide not to emigrate because to them emigration is impossible or not optimal.

By aggregating human capital stocks of all workers still in the country in new equilibrium, one can find:

$$\mathrm{H}_E = \mathrm{H}_E(h_0, \bar{f}, \Psi, \omega) \qquad (9)$$

Compare H_E and H_0 we will see the human capital stock in which case is higher. As $(h_0, \bar{f}, \Psi)$ are given, such difference $\Delta\mathrm{H} = (\mathrm{H}_E - \mathrm{H}_0)$ depends on ω.

Now, suppose that policy makers can affect Ψ, for each ω we examine function $\Delta\mathrm{H}(\Psi)$ and define as follows:

(i) If $\Delta\mathrm{H}(\Psi) \leq 0 \forall \Psi$: the source economy is in an "emigration trap."

(ii) If $\exists \Psi^* : \max \Delta\mathrm{H} = \Delta\mathrm{H}(\Psi^*) > 0$: existence of "optimal emigration constraints" Ψ^*.

The following sections present two models of emigration constraints. Section 3 presents a simple case in which emigration is possible to every worker, and the probability of successful emigration is the same to all (general emigration case). Section 4 provides a model in which only those whose bestowed human capital are higher than a certain level can emigrate, and their success probability depends on how much human capital they possess (brain drain case).

3. A Model of Optimal Emigration

3.1. Assumptions

In this model, some assumptions are added to simplify the general model.

First, the human capital formation function is assumed as:

$$h_i = c_i^{\alpha} \tau_i \quad (0 < \alpha < 1) \qquad (10)$$

Second, initial human capital endowment is zero. That means, a worker's life income is:

$$TU_i = -c_i + h_i(c_i, \tau_i). \qquad (11)$$

Third, the probability of emigration π is assumed exogenous and independent from h [3].

3.2. Solution

Following the above settings, we can solve for total human capital stocks of the source country in cases with and without emigration, and then compare the difference between them.

Human capital formation without emigration (H_0)***:***

[3] This assumption is similar to the "general emigration" assumption in Mountford 1997.

When there is no chance to emigrate, the worker's objective function is:

$$\underset{(c)}{Max}(TU_i) = -c_i + c_i^{\alpha}\tau_i$$

Solving the problem: $$\frac{\partial(TU_i)}{\partial c_i} = -1 + \alpha c_i^{\alpha-1}\tau_i = 0$$

$$\Rightarrow c_i^* = (\alpha\tau_i)^{\frac{1}{1-\alpha}} \tag{12}$$

$$\Rightarrow h_i^* = (c_i^*)^{\alpha}\tau_i = (\alpha)^{\frac{\alpha}{1-\alpha}}\tau_i^{\frac{1}{1-\alpha}} \tag{13}$$

Thus, the aggregate human capital formation of the economy without chance for emigration is:

$$\mathrm{H}_0 = \int_0^{\infty} h_0^*(\tau)n(\tau)d\tau \tag{14}$$

or: $$\mathrm{H}_0 = N\left((\alpha)^{\frac{\alpha}{1-\alpha}}\int_0^{\infty}\tau^{\frac{1}{1-\alpha}}f(\tau)d\tau\right) \tag{14.1}$$

Human capital formation with emigration (H_E)***:***

When it is possible to emigrate, the worker faces a probability π of going abroad and receiving the income $\omega(c_i^{\alpha}\tau_i)$, and a probability $(1-\pi)$ of staying to work in the home country and receiving an income $(c_i^{\alpha}\tau_i)$. Therefore, her expected income with chance of emigration is:

$$E(U_{Ei}) = \omega(c_i^{\alpha}\tau_i)\pi + (c_i^{\alpha}\tau_i)(1-\pi)$$

Now, her objective function is:

$$\underset{(c)}{Max}(TU_{Ei}) = -c_i + \omega(c_i^{\alpha}\tau_i)\pi + (c_i^{\alpha}\tau_i)(1-\pi)$$

Solving the problem by taking FOC:

$$\frac{\partial(TU_{Ei})}{\partial c_i} = -1 + \alpha c_i^{\alpha-1}\tau_i(1-\pi) + \omega\alpha c_i^{\alpha-1}\tau_i\pi = 0$$

$$\Leftrightarrow c_{iE}^* = [\alpha\tau_i(1+\gamma\pi)]^{\frac{1}{1-\alpha}} \tag{15}$$

where $\gamma = (w-1) > 0$.

Thus, the human capital to be accumulated by each worker is:

$$\Rightarrow h_{iE}^{*}=(c_{iE}^{*})^{\alpha}\tau_i=[\alpha(1+\gamma\pi)]^{\frac{\alpha}{1-\alpha}}\tau_i^{\frac{1}{1-\alpha}} \tag{16}$$

The aggregate human capital formation of the economy with chance for emigration is:

$$\mathrm{H}_E=\int_0^{\infty}h_E^{*}(\tau)n_E(\tau)d\tau$$

where n_{iE} is the number of worker at talent τ_i staying in the country. It is obvious that:

$$n_{iE}=(1-\pi)n_i=(1-\pi)N.f(\tau_i)$$

Then, $$\mathrm{H}_E=N\int_0^{\infty}[\alpha(1+\gamma\pi)]^{\frac{\alpha}{1-\alpha}}\tau^{\frac{1}{1-\alpha}}(1-\pi)f(\tau)d\tau$$

After rearranging: $$\mathrm{H}_E=(1+\gamma\pi)^{\frac{\alpha}{1-\alpha}}(1-\pi).N\left((\alpha)^{\frac{\alpha}{1-\alpha}}\int_0^{\infty}\tau^{\frac{1}{1-\alpha}}f(\tau)d\tau\right)$$

or: $$\mathrm{H}_E=(1+\gamma\pi)^{\frac{\alpha}{1-\alpha}}(1-\pi)\mathrm{H}_0 \tag{17}$$

Equation 17 expresses the aggregate domestic stock of human capital (H_E) as a function of possibility of emigration (π): $\mathrm{H}_E=\mathrm{H}_E(\pi)$.

If $\pi=0$: $\mathrm{H}_E=\mathrm{H}_0$. This is the case of no emigration.

If $\pi=1$: $\mathrm{H}_E=0$. This is the case of definitely free emigration. The economy's aggregate human capital is totally destroyed (or disappeared) because all human capital stock of the country will flow abroad where human capital income is higher.

We now consider the case $\pi\in(0,1)$. From (17) $\Rightarrow \mathrm{H}_E>0\,\forall\pi\in(0,1)\Rightarrow$ it is possible to take log both two sides of (17) and taking derivative with respect to π, and after rearranging the formulation:

$$\Rightarrow\frac{\partial\mathrm{H}_E}{\partial\pi}=\mathrm{H}_E\cdot\left(\frac{[(\gamma+1)\alpha-1]-\gamma\pi}{(1-\alpha)(1+\gamma\pi)(1-\pi)}\right)$$

Since $\mathrm{H}_E\left(\frac{1}{(1-\alpha)(1+\gamma\pi)(1-\pi)}\right)>0\,\forall\pi\in(0.1)\ \Rightarrow\ \mathrm{sign}\left[\frac{\partial\mathrm{H}_E}{\partial\pi}\right]=\mathrm{sign}\{[(\gamma+1)\alpha-1]-\gamma\pi\}$

Recall that $(\gamma+1)=\omega \;\Rightarrow$ $$\text{sign}\left[\frac{\partial \text{H}_E}{\partial \pi}\right] = \text{sign}\left[\frac{(\omega\alpha-1)}{(\omega-1)}-\pi\right] \tag{18}$$

Proposition 3.1: *If $\omega \leq \frac{1}{\alpha}$, the source economy always suffers from losing human capital stock regardless probability of emigration π. The higher the probability is, the more the country loses its human capital stock. This situation may be called "emigration trap."*

Proof. $\omega \leq \frac{1}{\alpha} \Rightarrow (\omega\alpha-1)\leq 0 \Rightarrow \left[\frac{(\omega\alpha-1)}{(\omega-1)}-\pi\right]\leq 0 \;\; \forall \pi > 0$

$\Rightarrow \frac{\partial \text{H}_E}{\partial \pi} \leq 0 \;\; \forall \pi>0 \;\Rightarrow \text{H}_E(\pi)$ is decreasing $\forall \pi > 0$, and $\text{H}_E \leq \text{H}_E(0)=\text{H}_0 \;\; \forall \pi>0$. □

In this case, the relationship between the domestic human capital stock H and the probability of emigration π is presented in Figure 2.

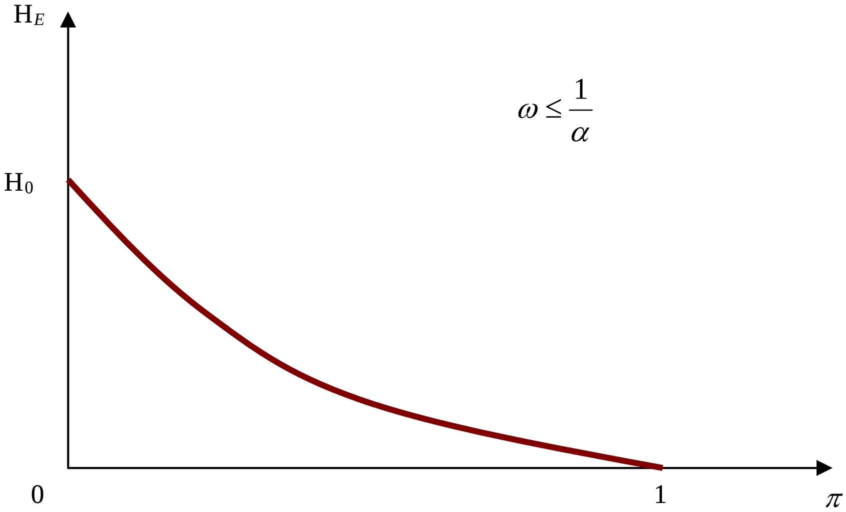

Figure 2. $\omega \leq \frac{1}{\alpha}$: **The economy in an "Emigration Trap"**

Proposition 3.2: *If $\omega > \frac{1}{\alpha}$, there exists a critical value of emigration probability $\pi^* = \frac{(\omega\alpha-1)}{\omega-1}$ maximizing domestic human capital stock. π^* is the "optimal emigration probability."*

Proof. $\omega > \frac{1}{\alpha} \Rightarrow (\omega\alpha-1)>0 \Rightarrow \exists \pi^* = \frac{(\omega\alpha-1)}{(\omega-1)} > 0$ so that:

$$\left[\frac{(\omega\alpha-1)}{\omega-1}-\pi\right]>0 \;\text{ if } \pi\in(0,\pi^*) \qquad \Leftrightarrow \frac{\partial \text{H}_E}{\partial \pi}>0 \;\text{ if } \pi \in (0,\pi^*)$$

$$\left[\frac{(\omega\alpha-1)}{\omega-1}-\pi\right]=0 \quad \text{if } \pi=\pi^{*} \qquad \Leftrightarrow \frac{\partial \mathrm{H}_E}{\partial \pi}=0 \quad \text{if } \pi=\pi^{*}$$

$$\left[\frac{(\omega\alpha-1)}{\omega-1}-\pi\right]<0 \quad \text{if } \pi\in(\pi^{*},1) \qquad \Leftrightarrow \frac{\partial \mathrm{H}_E}{\partial \pi}<0 \quad \text{if } \pi\in(\pi^{*},1)$$

$$\Rightarrow \mathrm{H}_E \text{ is maximized at } \mathrm{H}_E^M=\left[(1-\alpha)\alpha^{\frac{\alpha}{1-\alpha}}\frac{\omega^{\frac{1}{1-\alpha}}}{(\omega-1)}\right]\mathrm{H}_0 \text{ when } \pi=\pi^{*}=\frac{(\omega\alpha-1)}{(\omega-1)}. \qquad \square$$

Behavior of the domestic human capital stock is depicted in Figure 3.

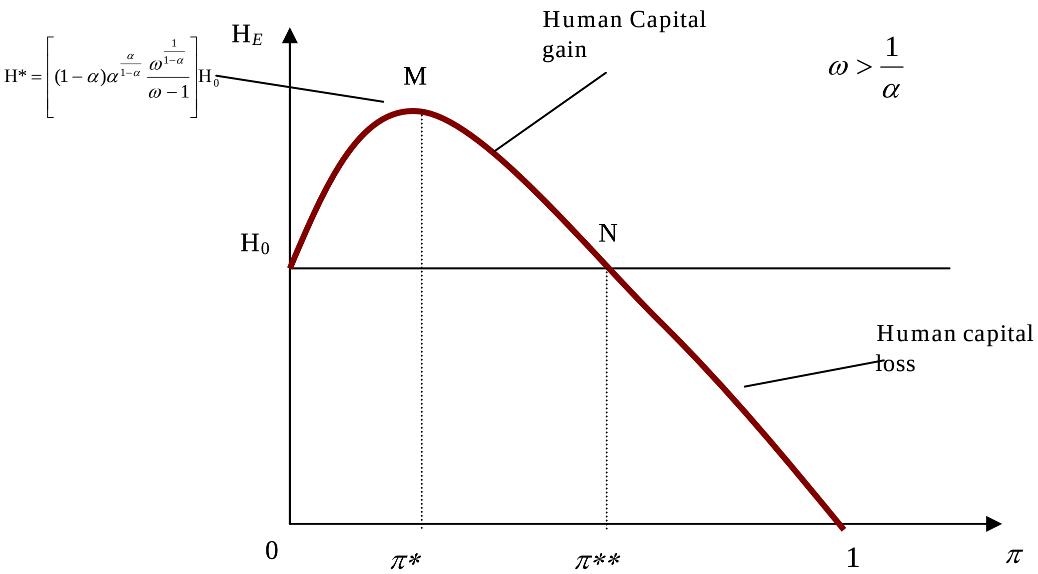

Figure 3. $\omega>\frac{1}{\alpha}$**: Existence of Optimal Emigration**

Proposition 3.2 shows that when the condition $\omega>\frac{1}{\alpha}$ is satisfied, a small probability of emigration at first will have positive effect on aggregate human capital formation of the source country, because "incentive" effect dominates "flight" effect. It is shown that there exists a critical value of emigration probability $\pi^{*}=\frac{(\omega\alpha-1)}{(\omega-1)}$ that maximizes the net human capital gain, or the aggregate domestic human formation (point M in Figure 3). If the possibility of emigration becomes higher, the net human capital gain will decrease, and at a level π^{**} [4] high

[4] π^{**} is the solution for the problem $(1+\gamma\pi)^{\frac{\alpha}{1-\alpha}}(1-\pi)=1$, as shown in Figure 3 at point N, where the curve $\mathrm{H}(\pi)$ intersects the horizontal line $\mathrm{H}=\mathrm{H}_0$.

enough, the "incentive" effect is dominated by the "flight" effect, making the total effect equal to zero. Finally, if emigration becomes certain (π=1), the economy will lose all of its human capital stock.

3.3. Effects of Wage Gaps (ω)

1. From Proposition 3.1. In the case $\omega \le \frac{1}{\alpha}$, the model implies that given domestic condition of the source country, the wage gap between the source and receiving countries is not high enough to create sufficient motivation for accumulating new human capital in the source country, therefore the out-flowing human capital is always larger than the newly created human capital.

Now, given the value of ω, if α is too small, making $\omega \le \frac{1}{\alpha}$, the source country is also deduced to a emigration trap. In our model, α can be understood as the source country's degree of technology of knowledge transfer or human capital formation. The higher α is, the more productive the formation is ($h_i = c_i^{\alpha}\tau_i$). A higher α means a more efficient education system or kinds of social organization, which allow more effective learning-by-doing. This condition shows the advantage in economic integration of those countries whose human capital formation capability is high.

Consequently, a policy implication is derived: improving domestic education quality and other ways of transferring knowledge, such as learning-by-doing in workplace, is a good reaction to an integrated world. When integrating into the world, wage and opportunity differential abroad will create a demand for education, but if the domestic education fails to meet the increasing demand, the country will lose its human capital.

2. From Proposition 3.2. When the condition $\omega > \frac{1}{\alpha}$ is satisfied, the model suggests that a positive probability of emigration is not always as bad as thought. It is not a zero-sum game between the source and the receiving countries. Emigration possibility motivates people in the source country to accumulate more human capital, and at an appropriate probability of emigration, the source country can gain human capital from this process (ie. brain gain from brain drain).

Moreover, there exists a value of emigration probability that maximizes the human capital gain of the source country. It is the point of optimal emigration. The source country's government can use emigration policies to control this probability to lead the economy to the optimality.

The model also confirms that, in any case, a sufficient high value of emigration probability will damage the source country's human capital stock (net loss of human capital). This means that a control in emigration is always necessary.

4. A Model of Optimal Brain Drain

4.1. Assumptions

In this model, the first two additional assumptions in the previous model are still kept, but the third assumption is adapted to the fact of brain drain that only workers whose human capital is greater than a certain level can emigrate, and worker's emigration probability π is dependent on her human capital stock h (endogenous emigration possibility). Intuitively, the following properties of π should hold:

(i) $\pi(h) > 0$ if $h > \overline{\eta}$, and $\pi(h) = 0$ otherwise;

(ii) $\frac{\partial \pi}{\partial h} > 0$ if $h > \overline{\eta}$ (higher skilled person is easier to emigrate);

(iii) $\lim_{h \to \overline{\eta}} \pi = 0$ (this condition guarantees the continuity of the function);

(iv) $\lim_{h \to \infty} \pi = 1$ (the person bestowed with extremely high skills can certainly emigrate).

For a concrete solution, we may assume: $\pi = \frac{h - \overline{\eta}}{h}$ if $h > \overline{\eta}$, and $\pi = 0$ otherwise. $\overline{\eta}$ may be considered as a threshold in emigration constraint policy. It is easy to see that $\pi(h)$ satisfies the properties above. The relationship between π and h is presented in Figure 4.

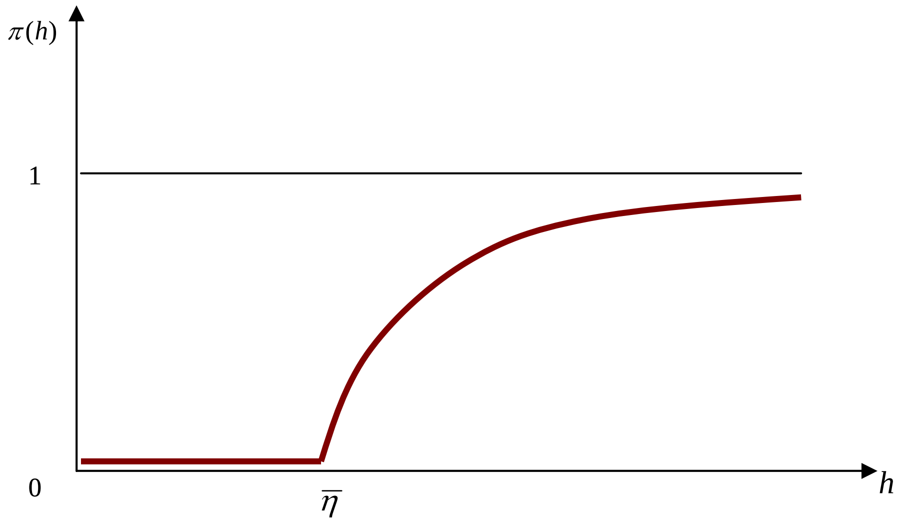

Figure 4. Emigration probability as a function of human capital

4.2. Solution

Following the same procedure in the case of general emigration, we first solve for total human capital stocks of the source country in cases with and without emigration, and then compare the difference between them.

Human capital formation without emigration (H_0)***:***

As shown in the general emigration case, equation 14, the aggregate human capital formation of the economy without chance for emigration is:

$$\mathrm{H}_0 = \int_0^\infty h_0^*(\tau) n(\tau) d\tau = (\alpha)^{\frac{\alpha}{1-\alpha}} \int_0^\infty \tau^{\frac{1}{1-\alpha}} n(\tau) d\tau$$

Human capital formation with emigration (H_E)***:***

In case of going abroad, a worker's expected income is:

$$E(U_{Ei}) = \omega h_{iE} \pi_i + h_{iE}(1-\pi_i) \tag{19}$$

where $h_{iE} = c_{iE}{}^{\alpha} \tau_i$ and $\pi_i = \dfrac{h_{iE} - \overline{\eta}}{h_{iE}}$.

Now, her objective function is:

$$\underset{(c)}{Max}(TU_{Ei}) = -c_{iE} + \omega h_{iE}\left(\frac{h_{iE} - \overline{\eta}}{h_{iE}}\right) + h_{iE}\left(1 - \frac{h_{iE} - \overline{\eta}}{h_{iE}}\right) = -c_{iE} + \omega(h_{iE} - \overline{\eta}) + \overline{\eta}$$

Solving the problem by taking FOC:

$$\frac{\partial(TU_{Ei})}{\partial c_{iE}} = -1 + \omega \frac{\partial h_{iE}}{\partial c_{iE}} = 0 \;\Leftrightarrow c_{iE}^* = (\omega \alpha \tau_i)^{\frac{1}{1-\alpha}} \tag{20}$$

Thus, the human capital to be accumulated by each worker is:

$$h_{iE}^* = (c_{iE}^*)^{\alpha} \tau_i = (\omega\alpha)^{\frac{\alpha}{1-\alpha}} \tau_i^{\frac{1}{1-\alpha}} \tag{21}$$

However, only those whose human capital is greater than $\overline{\eta}$ can have chance going abroad, therefore only those whose talent is greater than a critical level $\overline{\tau}$ that $h_{iE}^*(\overline{\tau}) = \overline{\eta}$ decide to invest in more education in hope of emigrating. Those whose talent is lower than $\overline{\tau}$ do not change their behavior, because in any case, they have no chance to emigrate. The shape of the human capital function $h(\tau)$, therefore, is a curve with a jump at $\overline{\tau}$ (See Figure 5).

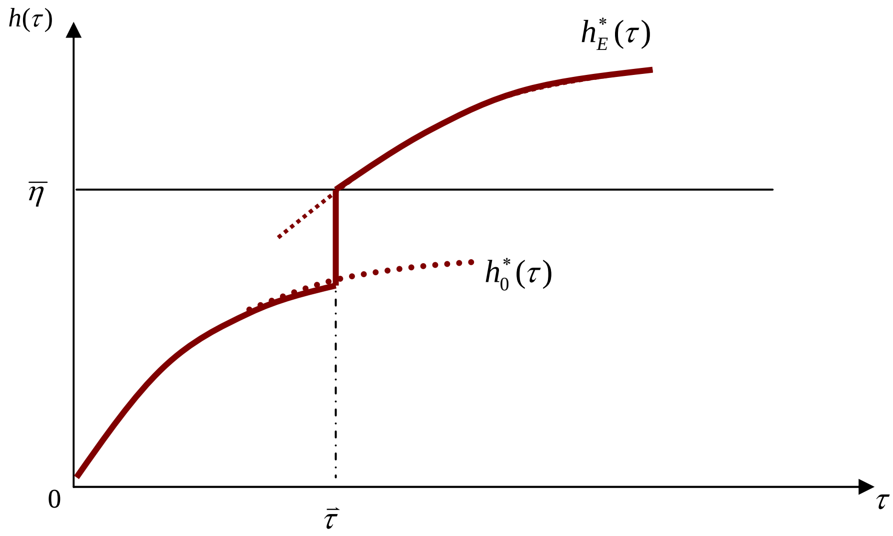

Figure 5. Human capital accumulation with brain drain

The relationship between $\overline{\tau}$ and $\overline{\eta}$ is: $\overline{\eta} = (\omega\alpha)^{\frac{\alpha}{1-\alpha}} \overline{\tau}^{\frac{1}{1-\alpha}}$ (22)

As a result, the aggregate human capital formation of the economy in this case is:

$$\mathrm{H}_E = \int_0^{\overline{\tau}} h_0^*(\tau)n(\tau)d\tau + \int_{\overline{\tau}}^{\infty} h_E^*(\tau)n_E(\tau)d\tau \tag{23}$$

where n_{iE} is the number of worker at talent τ_i staying in the country. It is obvious that:

$$n_{iE} = (1-\pi_i)n_i = \left(1 - \frac{h_{iE} - \overline{\eta}}{h_{iE}}\right)n(\tau_i) = \left(\frac{\overline{\eta}}{h_{iE}}\right)n(\tau_i)$$

Then,
$$\mathrm{H}_E = \int_0^{\overline{\tau}} h_0^*(\tau)n(\tau)d\tau + \int_{\overline{\tau}}^{\infty} h_E^*(\tau)\left(\frac{\overline{\eta}}{h_E^*(\tau)}\right)n(\tau)d\tau$$

$$\Rightarrow \mathrm{H}_E = \int_0^{\overline{\tau}} h_0^*(\tau)n(\tau)d\tau + \int_{\overline{\tau}}^{\infty} \overline{\eta}n(\tau)d\tau \tag{24}$$

The difference between H and H_0 is

$$\Delta\mathrm{H} = \mathrm{H} - \mathrm{H}_0 = \left[\int_0^{\overline{\tau}} h_0^*(\tau)n(\tau)d\tau + \int_{\overline{\tau}}^{\infty} \overline{\eta}n(\tau)d\tau\right] - \left[\int_0^{\infty} h_0^*(\tau)n(\tau)d\tau\right]$$

$$\Rightarrow \Delta\mathrm{H} = \left[\int_{\overline{\tau}}^{\infty} \overline{\eta}n(\tau)d\tau - \int_{\overline{\tau}}^{\infty} h_0^*(\tau)n(\tau)d\tau\right]$$

$$\Rightarrow \Delta\mathrm{H} = \int_{\bar{\tau}}^{\infty} \left[\bar{\eta} - h_0^*(\tau)\right] n(\tau) d\tau \qquad (25)$$

Recall from (13), (22) that $h_0^* = (\alpha)^{\frac{\alpha}{1-\alpha}} \tau^{\frac{1}{1-\alpha}}$ and $\bar{\eta} = (\omega\alpha)^{\frac{\alpha}{1-\alpha}} \bar{\tau}^{\frac{1}{1-\alpha}}$

$$\Rightarrow \Delta\mathrm{H} = (\alpha)^{\frac{\alpha}{1-\alpha}} N \int_{\bar{\tau}}^{\infty} \left[(\omega)^{\frac{\alpha}{1-\alpha}} \bar{\tau}^{\frac{1}{1-\alpha}} - \tau^{\frac{1}{1-\alpha}} \right] f(\tau) d\tau \qquad (26)$$

This means that one can rewrite: $\Delta\mathrm{H} = (\alpha)^{\frac{\alpha}{1-\alpha}} N \cdot \Omega(\bar{\tau})$ (27)

where : $\Omega(\bar{\tau}) = \int_{\bar{\tau}}^{\infty} \left[(\omega)^{\frac{\alpha}{1-\alpha}} \bar{\tau}^{\frac{1}{1-\alpha}} - \tau^{\frac{1}{1-\alpha}} \right] f(\tau) d\tau$. (28)

Now we investigate how $\Delta\mathrm{H}$ depends on $\bar{\tau}$ (recall that $\bar{\tau}$ depends on the value of $\bar{\eta}$, as shown in equation 22).

Note that if $\bar{\eta}$ =0 ($\bar{\tau}$ = 0), or there is no restriction of emigration

$$\Rightarrow \Delta\mathrm{H} = -(\alpha)^{\frac{\alpha}{1-\alpha}} N \int_{0}^{\infty} \tau^{\frac{1}{1-\alpha}} f(\tau) d\tau = -\mathrm{H}_0$$

This is consistent with the extreme case, when all human capital flies out of the source country.

In another extreme, if $\bar{\eta} \to \infty$, leading to $\bar{\tau} \to \infty \Rightarrow \Delta\mathrm{H} = 0$, or the case of closed economy.

Between the two extremes, $\Delta\mathrm{H}$ will change in its range of ($-\mathrm{H}_0$, 0) due to the change of $\bar{\eta}$ in its domain of $(0, \infty)$, or as $\bar{\tau} \in (0, \infty)$ respectively. Our purpose now is to examine such functional relationship between $\Delta\mathrm{H}$ and $\bar{\eta}$ (or $\bar{\tau}$).

Because $\alpha > 0$, N>0, we can therefore sufficiently investigate the change of the value of $\Omega(\bar{\tau})$ as $\bar{\tau}$ changes. Rewrite equation 28 as

$$\Omega = (\omega)^{\frac{\alpha}{1-\alpha}} \bar{\tau}^{\frac{1}{1-\alpha}} \int_{\bar{\tau}}^{\infty} f(\tau) d\tau - \int_{\bar{\tau}}^{\infty} \tau^{\frac{1}{1-\alpha}} f(\tau) d\tau \qquad (29)$$

and set $\tau^{\frac{1}{1-\alpha}} = u$ and $f(\tau) d\tau = dv$ (so that $v = F(\tau)$, cdf of workers at talent τ).

$$\Rightarrow \int_{\bar{\tau}}^{\infty} \tau^{\frac{1}{1-\alpha}} f(\tau) d\tau = \int_{\bar{\tau}}^{\infty} u dv = uv - \int_{\bar{\tau}}^{\infty} v du$$

$$= \left[\tau^{\frac{1}{1-\alpha}} F(\tau) \right] \Bigg|_{\bar{\tau}}^{\infty} - \frac{1}{1-\alpha} \int_{\bar{\tau}}^{\infty} F(\tau) \tau^{\frac{\alpha}{1-\alpha}} d\tau$$

Plug into (29):

$$\Rightarrow \Omega = \left[(\omega)^{\frac{\alpha}{1-\alpha}} \bar{\tau}^{\frac{1}{1-\alpha}} \right] \left[F(\tau)\Big|_{\bar{\tau}}^{\infty} \right] - \left[\tau^{\frac{1}{1-\alpha}} F(\tau) \right] \Bigg|_{\bar{\tau}}^{\infty} + \frac{1}{1-\alpha} \int_{\bar{\tau}}^{\infty} F(\tau) \tau^{\frac{\alpha}{1-\alpha}} d\tau$$

Now we take the first derivative of Ω with respect to $\bar{\tau}$. Because the upper bound does not depend on $\bar{\tau}$, its derivative must be zero and eliminated from the equation:

$$\frac{\partial \Omega}{\partial \bar{\tau}} = \frac{\partial \left[\left((\omega)^{\frac{\alpha}{1-\alpha}} \bar{\tau}^{\frac{1}{1-\alpha}} \right) \left(1 - F(\bar{\tau}) \right) \right]}{\partial \bar{\tau}} + \frac{\partial \left(\bar{\tau}^{\frac{1}{1-\alpha}} F(\bar{\tau}) \right)}{\partial \bar{\tau}} - \frac{1}{1-\alpha} \left(F(\bar{\tau}) \bar{\tau}^{\frac{\alpha}{1-\alpha}} \right)$$

Remember that $\frac{\partial F(\tau)}{\partial \tau} = f(\tau) \forall \tau$:

$$\Rightarrow \frac{\partial \Omega}{\partial \bar{\tau}} = (\omega)^{\frac{\alpha}{1-\alpha}} \left[\frac{1}{1-\alpha} \bar{\tau}^{\frac{\alpha}{1-\alpha}} \left(1 - F(\bar{\tau}) \right) + \bar{\tau}^{\frac{1}{1-\alpha}} (-f(\bar{\tau})) \right] +$$

$$+ \left[\frac{1}{1-\alpha} \bar{\tau}^{\frac{\alpha}{1-\alpha}} F(\bar{\tau}) + \bar{\tau}^{\frac{1}{1-\alpha}} f(\bar{\tau}) \right] - \frac{1}{1-\alpha} \left(F(\bar{\tau}) \bar{\tau}^{\frac{\alpha}{1-\alpha}} \right)$$

Rearrange the right hand side:

$$\Rightarrow \frac{\partial \Omega}{\partial \bar{\tau}} = \bar{\tau}^{\frac{\alpha}{1-\alpha}} \left(1 - F(\bar{\tau}) \right) \left\{ \left[\frac{1}{(1-\alpha)} \frac{\omega^{\frac{\alpha}{1-\alpha}}}{(\omega^{\frac{\alpha}{1-\alpha}} - 1)} \right] - \frac{\bar{\tau} \cdot f(\bar{\tau})}{\left(1 - F(\bar{\tau}) \right)} \right\}$$

Denote: $$K = \left[\frac{1}{(1-\alpha)} \frac{\omega^{\frac{\alpha}{1-\alpha}}}{(\omega^{\frac{\alpha}{1-\alpha}} - 1)} \right] \Rightarrow K \in (1, +\infty), \tag{30}$$

and $$g(\bar{\tau}) = \frac{\bar{\tau} \cdot f(\bar{\tau})}{\left(1 - F(\bar{\tau}) \right)} \geq 0, \tag{31}$$

$$\Rightarrow \frac{\partial \Omega}{\partial \bar{\tau}} = \bar{\tau}^{\frac{\alpha}{1-\alpha}} (1 - F(\bar{\tau})) \left[K - g(\bar{\tau}) \right] \tag{32}$$

Now, plug into (27) to get:

$$\frac{\partial \Delta \mathrm{H}}{\partial \overline{\tau}} = (\alpha)^{\frac{\alpha}{1-\alpha}} N \cdot \frac{\partial \Omega(\overline{\tau})}{\partial \overline{\tau}},$$

and denote : $$A = N(\alpha)^{\frac{\alpha}{1-\alpha}} \overline{\tau}^{\frac{\alpha}{1-\alpha}} (1 - F(\overline{\tau})) \geq 0, \tag{33}$$

We can then derive from (32): $\frac{\partial \Delta \mathrm{H}}{\partial \overline{\tau}} = A \cdot [K - g(\overline{\tau})]$

or: $$\frac{\partial \Delta \mathrm{H}}{\partial \overline{\eta}} = \left(\frac{\partial \overline{\eta}}{\partial \overline{\tau}} \right)^{-1} A \cdot [K - g(\overline{\tau})] \tag{34}$$

As $\left(\frac{\partial \overline{\eta}}{\partial \overline{\tau}} \right)^{-1} > 0$ (from equation 22), $A > 0 \ \forall \overline{\tau} > 0$, we finally come to the following equation:

$$\operatorname{sign} \frac{\partial \Delta \mathrm{H}}{\partial \overline{\eta}} = \operatorname{sign}[K - g(\overline{\tau})] \tag{35}$$

Equation 35 is important because by examining the sign of $[K - g(\overline{\tau})]$, we can understand how $\Delta \mathrm{H}$ changes as $\overline{\eta}$ varies.

Because $f(\overline{\tau})$ is given and so far we do not have more assumptions concerning its properties, in general we have no clear-cut conclusion of the shape of function $g(\overline{\tau})$. However, (31) reveals some basic features of $g(\overline{\tau})$:

(i) $g(0) = 0$; and

(ii) $g(\overline{\tau}) > 0 \ \ \forall \overline{\tau} > 0$.

We now concern the upper limit of $g(\overline{\tau})$. In general, $g(\overline{\tau})$ can converge or diverge. But, for our current purpose, we consider the case of divergence is merely a special case of convergence to $+\infty$. We can therefore distinguish two cases:

(A) $\lim_{\overline{\tau} \to \infty} g(\overline{\tau}) > K$ (including $\lim_{\overline{\tau} \to \infty} g(\overline{\tau}) = +\infty$)

(B) $\lim_{\overline{\tau} \to \infty} g(\overline{\tau}) < K$

Proposition 4.1: *If* $\lim_{\overline{\tau} \to \infty} g(\overline{\tau}) > K$ *(Case A), there exists a critical level of* $\overline{\eta}^{**}$ *that above it the source economy will have brain gain from brain drain (*$\Delta \mathrm{H}$ *becomes positive). There also exists a level of* $\overline{\eta}^{*}$ *maximizing the net brain gain (*$\Delta \mathrm{H}$ *is maximized and positive), or the "optimal brain drain" value of* $\overline{\eta}$.

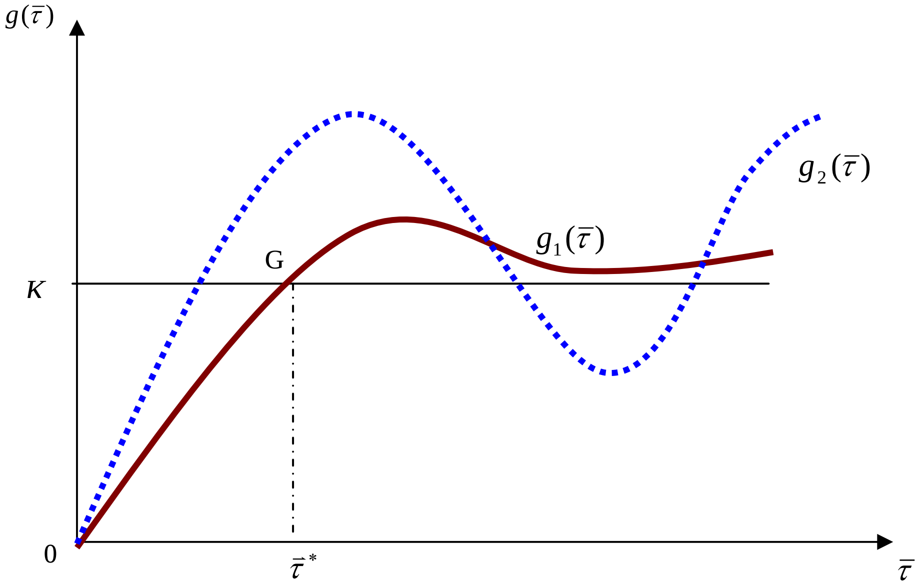

Figure 6. Case A: $g(\overline{\tau})$ converges to a value greater than *K*

Proof. *(i) Existence of* $\overline{\eta}^{**}$: As $\lim_{\overline{\tau}\to\infty} g(\overline{\tau}) > K \Rightarrow \lim_{\overline{\tau}\to\infty}[K - g(\overline{\tau})] < 0 \Rightarrow \text{sign} \lim_{\overline{\eta}\to\infty} \frac{\partial \Delta \text{H}}{\partial \overline{\eta}} =$ $\text{sign} \lim_{\overline{\tau}\to\infty} A[K - g(\overline{\tau})] < 0$. We also know that $\lim_{\overline{\eta}\to\infty} \Delta\text{H} = 0$, therefore, as $\overline{\eta}$ approaches $+\infty$, ΔH must approach zero *from above*. This means that at a great enough value of $\overline{\eta}$, ΔH must be greater than zero, and, consequently, there must exist at least one point where ΔH exceeds zero. Such a point is illustrated as point N in Figure 7.

(ii) Existence of $\overline{\eta}^*$: As $g(\overline{\tau})$ is continuous, and $g(0) = 0 < K$ and $\lim_{\overline{\tau}\to\infty} g(\overline{\tau}) > K$, $g(\overline{\tau})$ must somewhere exceed the horizontal line $k(\overline{\tau}) = K$, or where $[K - g(\overline{\tau})] = 0$. Suppose it is point G in Figure 6 (take $g_1(\overline{\tau})$ for example). That "$g_1(\overline{\tau})$ exceeds $k(\overline{\tau}) = K$ at G" necessarily means that "$g(\overline{\tau})$ is increasing in $\overline{\tau}$ at G," or, mathematically, $\frac{\partial g(\overline{\tau}^*)}{\partial \overline{\tau}^*} > 0$. These facts imply that $\exists$ at least one value of $\overline{\tau}^*$ so that: $[K - g(\overline{\tau}^*)] = 0$ and $\frac{\partial [K - g(\overline{\tau}^*)]}{\partial \overline{\tau}^*} = -\frac{\partial g(\overline{\tau}^*)}{\partial \overline{\tau}^*} < 0$. By recalling (35) and defining $\overline{\eta}^*$ = $\eta(\overline{\tau}^*)$ as in (20), one comes to an equivalent conclusion that $\frac{\partial \Delta\text{H}}{\partial \overline{\eta}^*} = [K - g(\overline{\tau}^*)] = 0$ and $\text{sign} \frac{\partial^2 \Delta\text{H}}{\partial \overline{\eta}^{*2}} = \text{sign} \frac{\partial [K - g(\overline{\tau}^*)]}{\partial \overline{\tau}^*} < 0 \Rightarrow \Delta\text{H}$ maximizes at $\overline{\eta}^*$ (see Figure 7)[5] . □

[5] Since an exact from of $g(\overline{\tau})$ is not known, there may be multiple roots (as $g(\overline{\tau})$ has a shape like $g_2(\overline{\tau})$ in Figure 6). To keep the illustration simple but without loss of the general implications, we will consider the case of unique root only (curve $g_1(\overline{\tau})$ in Figure 6 and $\Delta\text{H}_1(\overline{\eta})$ in Figure 7). The cases of multiple roots are presented in the figures as the dashed curves.

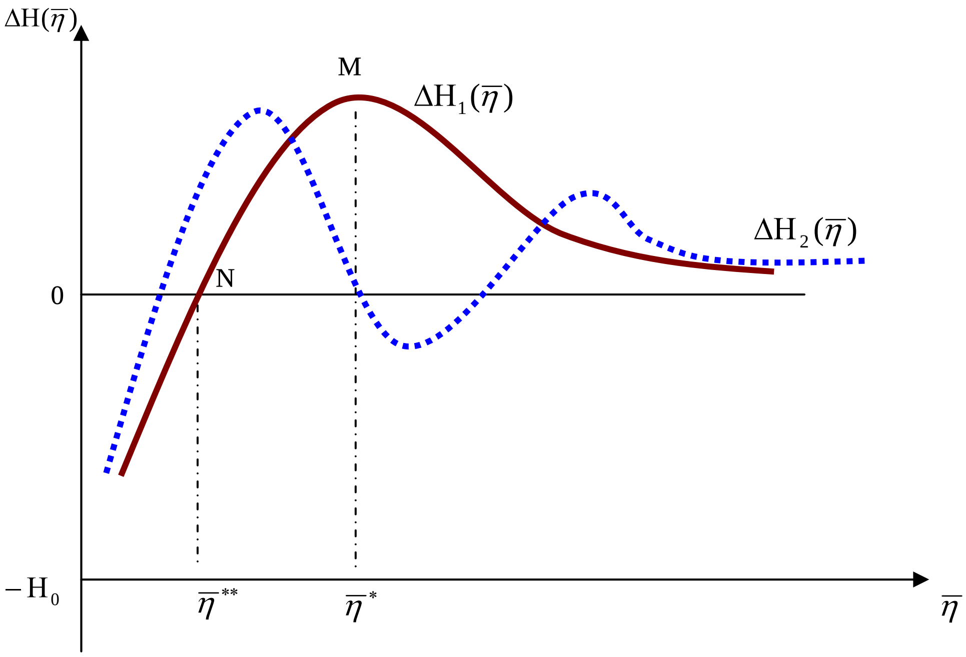

Figure 7. Existence of Optimal Brain Drain in Case A

Proposition 4.2: *If* $\lim_{\bar{\tau}\to\infty} g(\bar{\tau}) < K$ *(Case B), the existence of optimal brain drain is inconclusive. Depending on the particular properties of the talent probability density function, the source economy may (i) always loss its human capital at any level of* $\overline{\eta}$ *- the case of "brain drain trap", or (ii) gain human capital only in limited ranges of* $\overline{\eta}$ *.*

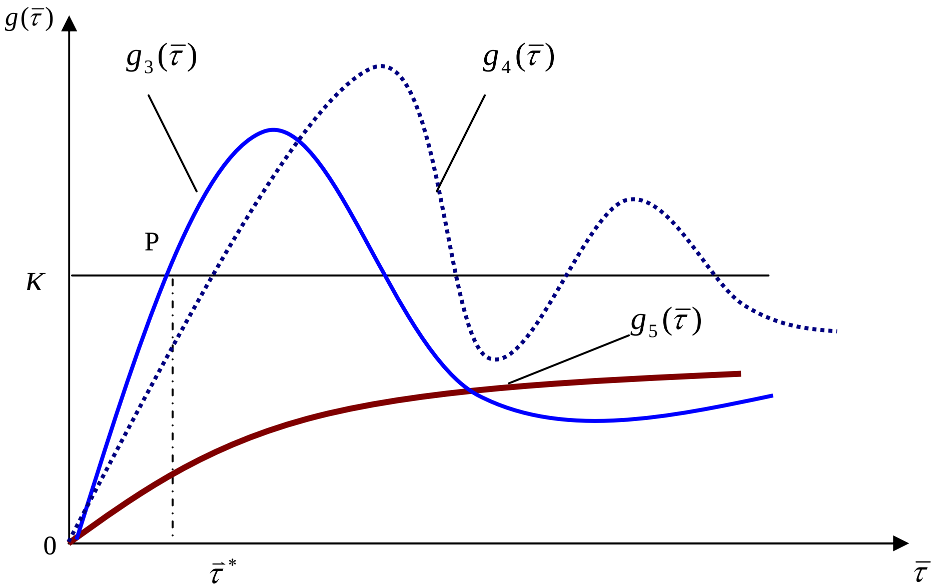

Figure 8. Case B: $g(\bar{\tau})$ **converges to a value smaller than** ***K***

Proof: As $\lim_{\bar{\tau}\to\infty} g(\bar{\tau}) < K$ (see Figure 8 for different possible shapes of $g(\bar{\tau})$) $\Rightarrow \lim_{\bar{\tau}\to\infty}[K - g(\bar{\tau})] > 0$ $\Rightarrow \text{sign} \lim_{\bar{\eta}\to\infty} \frac{\partial \Delta H}{\partial \bar{\eta}} = \text{sign} \lim_{\bar{\tau}\to\infty}[K - g(\bar{\tau})] > 0 \Rightarrow \lim_{\bar{\eta}\to\infty} \frac{\partial \Delta H}{\partial \bar{\eta}} > 0$. Therefore, as $\bar{\eta}$ approaches $+\infty$, $\Delta H(\bar{\eta})$ must approach zero *from below*. In addition, that $g(\bar{\tau})$ may sometimes exceed the horizontal line $k(\bar{\tau}) = K$ or always below such line $\forall \bar{\tau}$ suggests that $\Delta H(\bar{\eta})$ may have maxima or may not have at all, respectively. These facts imply that there are 3 possible sub-cases:

(B1) Existence of positive maxima of ΔH (ΔH_3 and ΔH_4 in Figure 9)

(B2) Non-Existence of positive maxima of ΔH, and consequently, ΔH is a non-positive function (ΔH_5 in Figure 10)

(B3) Non-existence of maxima of ΔH, and, consequently, ΔH is a strictly negative function (ΔH_6 in Figure 10)

Thus, in sub-case B1 there exists optimal brain drain, but the range where net brain gain is positive is limited in some intervals of $\bar{\eta}$ (in Figure 9, see the parts of the curves above horizontal axis). Take curve ΔH_3 for example: $\Delta H > 0$ only when $\bar{\eta} \in (\bar{\eta}_1, \bar{\eta}_2)$.

In sub-cases B2, B3, ΔH is non-negative $\forall \bar{\eta}$ (Figure 10). This implies that the source economy suffers from losing human capital at all level of $\bar{\eta}$. It is by our definition the case of "brain drain trap."

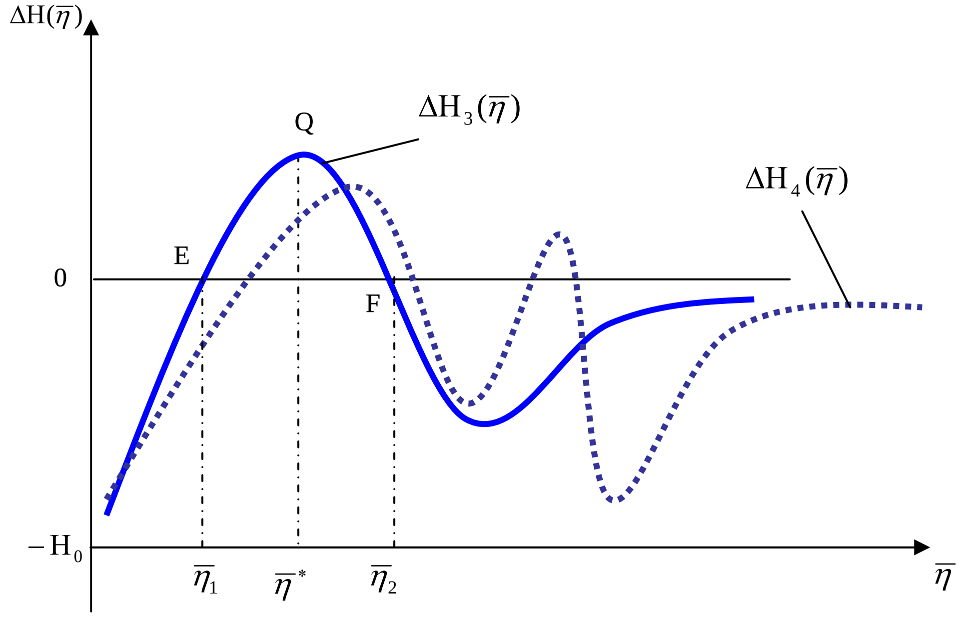

Figure 9. Existence of Optimal Brain Drain (Case B1)

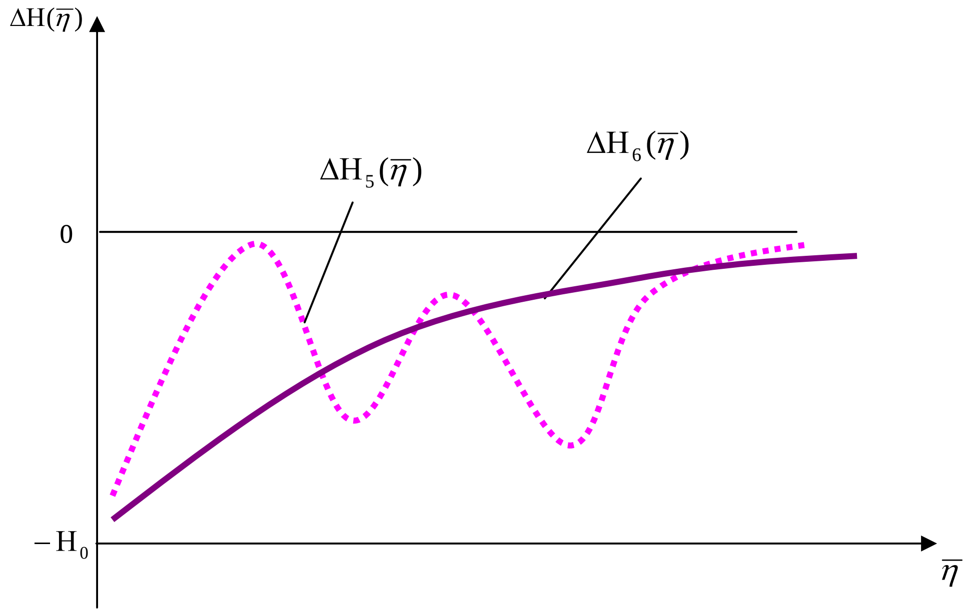

Figure 10. Brain Drain Trap (Cases B2, B3)

4.3. Effects of Wage Gaps (ω)

In this section, we examine how changes in wage difference between the receiving and the source countries (ω) affect the net brain gain function, $\Delta H(\overline{\eta})$, and optimal brain drain level of threshold human capital $\overline{\eta}^*$.

1. Effects of ω *on* $\Delta H(\overline{\eta})$. From equation 26, we know that:

$$\frac{\partial \Delta H}{\partial \omega} = \frac{\alpha}{1-\alpha}(\alpha)^{\frac{\alpha}{1-\alpha}} \overline{\tau}^{\frac{1}{1-\alpha}} N(1-F(\overline{\tau}))(\omega)^{\frac{2\alpha-1}{1-\alpha}} \geq 0 \tag{36}$$

Therefore, at any given rate of threshold human capital level $\overline{\eta}$, when ω increases (decreases), the net brain gain will increase (decrease).

2. Effects of ω *on* $\overline{\eta}^*$.

As $\frac{\partial \overline{\eta}}{\partial \overline{\tau}} > 0 \forall \overline{\tau}$, $\frac{\partial g(\overline{\tau}^*)}{\partial \overline{\tau}^*} > 0$ (see Proof of Proposition 4.1), and $K = g(\overline{\tau}^*)$,

$$\Rightarrow \frac{\partial \overline{\eta}^*}{\partial K} = \frac{\partial \overline{\eta}^*}{\partial \overline{\tau}^*}\frac{\partial \overline{\tau}^*}{\partial K} = \frac{\partial \overline{\eta}^*}{\partial \overline{\tau}^*}\frac{\partial \overline{\tau}^*}{\partial g(\overline{\tau}^*)} > 0 \tag{37}$$

From (30):
$$\Rightarrow \frac{\partial K}{\partial \omega} = -\frac{\alpha \omega^{\frac{2\alpha-1}{1-\alpha}}}{[(1-\alpha)(\omega^{\frac{\alpha}{1-\alpha}}-1)]^2} < 0 \tag{38}$$

Combine (37) and (38), one gets: $\frac{\partial \overline{\eta}^*}{\partial \omega} = \frac{\partial \overline{\eta}^*}{\partial K}\frac{\partial K}{\partial \omega} < 0$ (39)

3. Shift of the curve $\Delta H(\overline{\eta})$ as ω changes.

From properties of (34) and (37), one can derive the behavior of the net brain drain function $\Delta H(\overline{\eta})$ when ω changes, as shown in Figure 11. For example, when ω increases, the curve $\Delta H(\overline{\eta})$ will shift upwards (from $\Delta H_{\omega 1}$ to $\Delta H_{\omega 2}$), and at the same time, the maximum point shifts backwards (from M_1 to M_2).

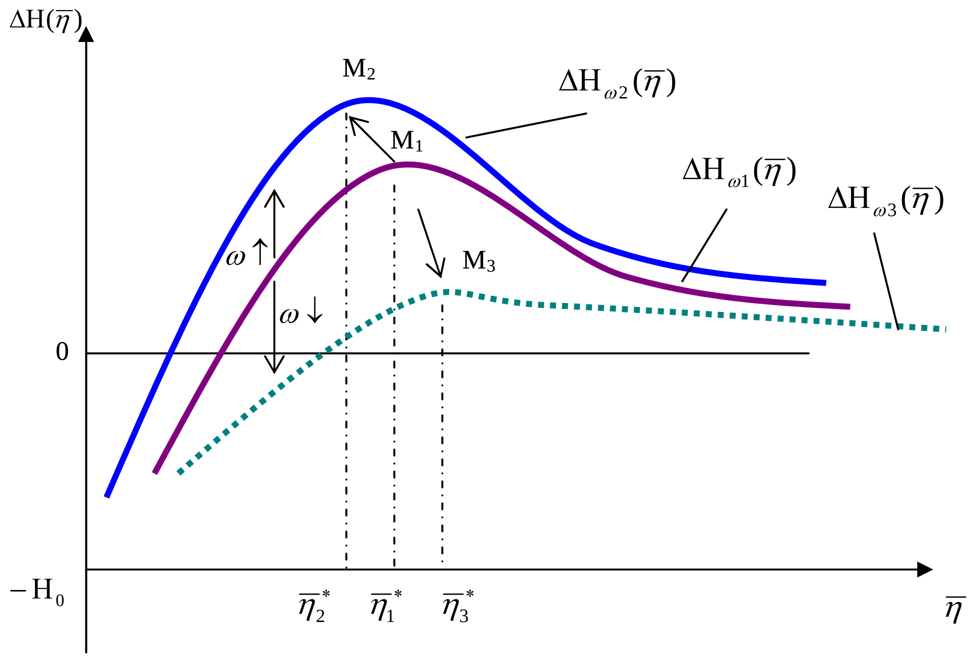

Figure 11. Shifts of $\Delta H(\overline{\eta})$ by changes in ω

Figure 11 describes how $\Delta H(\overline{\eta})$ moves as ω changes. When ω decreases, for example, the curve becomes flatter and lower, and tends to move outwards (as the maximum value increases). As a result, net brain gain becomes smaller and approaches zero. This implies a fact that when income gap is big, the incentive to accumulate more human capital is higher and strongly dominates the real loss of human capital bestowed in actual emigrants. Consider the optimal level of emigration threshold ($\overline{\eta}^*$), we find that the country with lower wage rate may be suggested to choose a lower level than the country with higher wage rate (or smaller income gap). This finding is interesting, because it implies that the poorer countries should be more open its market of the highly skilled (and nominally involves more brain drain) to the world in order to accumulate more human capital.

5. Conclusion

In this paper I have constructed models of optimal emigration with workers' heterogeneous talents. The models prove that under some conditions the source country may get stuck in a "brain drain trap," where emigration constraints always leads to *net brain drain*, or the brain drain effect at all times dominates the brain gain effect. However, if the source country is not in a "brain drain trap," it possibly accumulates human capital by allowing a certain possibility of emigration.

In the case of general emigration, an emigration possibility small enough may create motivation for human capital accumulation in the source country. Consequently, the model in this case shows two critical points in this process: an "optimal emigration probability", where the source country is able to get maximum human capital stock; and a "net brain drain probability" where the source country begins to lose its human capital.

In the case of brain drain, ie, only workers with human capital bestowed higher than a certain threshold may emigrate, and the higher skilled workers are easier to go, we also show that policy makers can affect such threshold to maximize the domestic aggregate human capital formation. Conditions for existence of brain gain from brain drain, however, depend on the distribution of workers' talent. A conclusion of the existence is only achieved by examining in more details the properties of such distribution function.

The models proposed in this paper are simple and static. Although they are simplified in many ways, their message is basic and straightforward. For further studies, we may examine the progress of human capital stock in a dynamic framework, using overlapping generation approach with human capital bequest from workers' parents. A more comprehensive study may consider externality of human capital as suggested by Lucas (1988). Moreover, to investigate the dynamics of an education sector facing increasing demand may bring interesting results. Finally, concerning education policy in open economies, we can analyze the country's welfare with different patterns of education (i.e. public versus private investment in education and training, credit with and without constraints, etc.) in presence of emigration.

Reference

Barro, Robert and Xavier Sala-I-Martin, 2004. *Economic Growth.* Cambridge, Mass: MIT Press.

Beine, Michel; Frederic Docquier and Hillel Rapoport, 2003. "Brain Drain and LDCs' Growth: Winners and Losers." Working paper.

Beine, Michel; Frederic Docquier and Hillel Rapoport, 2001. "Brain Drain and Economic Growth: Theory and Evidence." *Journal of Development Economics*, 64: 275-289.

Bhagwati, Jagdish N. and Koichi Hamada, 1974. "The Brain Drain, International Integration of Markets for Professionals and Unemployment: A Theoretical Analysis." *Journal of Development Economics*, 1: 19-24.

Bhagwati, Jagdish N., ed., 1976. *The Brain Drain and Taxation, Vol. II: Theory and Empirical Analysis*. Amsterdam: North-Holland.

Bhagwati, Jagdish N., 1979. "International Migration of the Highly Skilled: Economics, Ethics and Taxes." *Third World Quarterly*, 1: 17-30.

Bhagwati, Jagdish N., 1979. "The Economic Analysis of International Migration." Lecture delivered to Nordic Council of Ministers, Oslo, Norway, reprinted in Bhagwati, Jagdish N., *International Factor Mobility (Essays in International Economic Theory, Vol. II.* Cambridge, Mass: MIT Press (1987).

Bhagwati, Jagdish N. and Martin Partington, eds., 1976. *Taxing the Brain Drain, Vol.. I: A Proposal*. Amsterdam: North-Holland.

Dos Santos, Manon D. and Fabien Postel-Vinay, 2003. "Migration as a Source of Growth: The Perspective of a Developing Country," *Journal of Population Economics*, 16: 161-175.

Drinkwater, Stephen; Paul Levine; Emanuela Lotti and Joseph Pearlman, 2002. "The Economic Impact of Migration: A Survey," paper prepared for the second Workshop of the Fifth Framework Programme Project "European Enlargement: The Impact of East-West Migration on Growth and Employment," Vienna, 6-7th December.

Hamada, Koichi, 1977. "Taxing the Brain Drain: A Global Point of View," in J. N. Bhagawati, ed., *The New International Economic Order: The North-South Debate.* Cambridge, Mass: MIT Press.

Khwaja, Yasmeen and Pasquale Scaramozzino, 2003. "Unknown Talents and the Brain drain: The Informational Role of Migration," discussion paper.

Kwok, Viem; Hayne Leland, 1982. "An Economic Model of the Brain Drain," *The American Economic Review,* 72: 91-100.

Lowell, B. Lindsay, 2002. "Some Developmental Effects of the International Migration of Highly Skilled Persons." *International Migration Papers,* No. 46, International Labour Office, Geneva.

Lowell, B. Lindsay and Allan Findlay, 2002. "Migration of Highly Skilled Persons from Developing Countries: Impact and Policy Responses," *International Migration Papers*, No. 44, International Labour Office, Geneva.

Lucas, Robert E. Jr., 1988 "On the Mechanics of Economic Development." *Journal of Monetary Economics*, 22: 3-42.

Miyagiwa, Kaz, 1991. "Scale Economics in Education and the Brain Drain Problem." *International Economic Review*, 32: 743-759.

Mountford, Andrew, 1997. "Can a Brain Drain be Good for Growth in the Source Economy?" *Journal of Development Economics*, 53: 287-303.

Rapoport, Hillel, 2002. "Who is Afraid of the Brain Drain? Human Capital Flight and Growth in Developing Countries." *Policy Brief*, Stanford Institute for Economic Policy Research, Stanford.

Stark, Oded, 2004. "Rethinking Brain Drain." *World Development*, 32: 15-22.

Stark, Oded, Christian Helmenstein, Alexia Prskawetz, 1997. "A Brain Gain with a Brain Drain." *Economics Letters*, 55: 227-234.

Stark, Oded; Christian Helmenstein; Alexia Prskawetz, 1998. "Human Capital Depletion, Human Capital Formation, and Migration: a Blessing or a "Curse"?" *Economics Letters*, 60: 363-267.

Stark, Oded; Yong Wang, 2002. "Inducing Human Capital Formation: Migration as a Substitute for Subsidies." *Journal of Public Economics*, 86: 29-46.

Vidal, Jean-Pierre, 1998. "The Effect of Emigration on Human Capital Formation," *Journal of Population Economics*, 11: 589-600.