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Human Capital, Migration Strategy, and Brain Drain

PETER SCHAEFFER
Division of Resource Management, West Virginia University, Morgantown, USA

ABSTRACT *This research was motivated by the increasing number of foreign students and scientists who are in the United States on temporary visas and who are able to change their status to permanent immigrant. Origin countries, among them industrialized western European nations, are concerned about losing many of their best-educated and most talented citizens. This article modifies and extends a theoretical model of optimal human capital investment before and after migration to shed new light on the emigration/immigration of the highly skilled, and explores some possible implications for the study of the so-called 'brain drain' phenomenon.*

KEY WORDS: Brain drain, emigration, human capital, immigration, self-selection, immigration strategy

Introduction

Foreign students and scientists who are in the United States on temporary visas can try to change their status to permanent immigrant. During the 1990s, the number of such visa conversions grew significantly (National Science Foundation 1996: 7): 'Prior to 1991, most S&E immigrants[1] in a given year were new arrivals; only a minority were already in the United States and had their resident status adjusted from temporary to permanent. Data for 1991 show proportions of both new arrivals and adjustments-of-status cases to be roughly equal, whereas in 1992, adjustment-of-status cases increased to 65 percent of S&E immigration. This trend continued in 1993, with 68.5 percent of all S&E immigration resulting from adjustment-of-status cases.' Additional information is provided in another report by the National Science Foundation (1998). Of the 656,500 doctoral scientists in the United States in 2001, 9 per cent

Correspondence Address: Peter Schaeffer, Division of Resource Management, West Virginia University, PO Box 6108, Morgantown, WV 26506-6108, USA.
E-mail: Peter.Schaeffer@mail.wvu.edu

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were non-citizens and 14 per cent were naturalized US citizens (National Science Foundation 2004a). In 2002, 145,112 international students on temporary visas and 310,243 US citizens and permanent residents were enrolled in graduate science and engineering programmes in the United States, while 18,573 scholars on temporary visas and 13,502 US citizens and permanent residents held post-doctoral fellowships (Thurgood, 2004; for additional information on international students in the United States, see Chin, 2003).

Saxenian (1999) reports a related finding in a study of the role of immigrant engineers and scientists in Silicon Valley's high technology industry. She found that in 1998 a quarter of Silicon Valley's high technology firms were led by Chinese or Indian immigrant senior executives, the majority of them individuals who had come to attend graduate school in the United States and stayed (Saxenian, 1999). Of course, we do not know whether the change in status from student to permanent immigrant was planned ahead of time as part of a deliberate strategy, or whether it was the result of opportunities that were unanticipated at the time of entry as students. However, even if initially visa conversions were a lucky break for those who obtained them, the growing number of successful conversions is likely to attract attention and lead some highly skilled prospective immigrants to see studies or post-doctoral work as a stepping stone toward permanent resident status. Indirect empirical support for this expectation comes from yet another National Science Foundation (1999) study.

It is not altogether clear why resident status adjustments among immigrant scientists and engineers have been increasing. It might simply reflect the fast growth of job opportunities in the United States. The number of jobs requiring science and engineering skills in the United States has been growing almost 5 per cent per year, while the number of other jobs has been increasing at a rate of only slightly above 1 per cent (National Science Foundation 2004b).

To study this growing phenomenon, we develop a theoretical model of the relationship between immigration and human capital. It is difficult to distinguish empirically between human capital investment as a strategy to gain access to a desired labour market in the destination country and human capital investments made before and after emigration in response to local labour market conditions in the destination country. The two human capital investment decisions are intertwined, and it may not be possible to separate them using data representing only successful immigrants, and data that includes those who stay behind do not currently seem to be available. The theoretical analysis in this article explores issues and defines questions more precisely. In the process we gain insights that can inform later empirical work, from data collection to its analysis.

The premise of this study is that some prospective immigrants will strategically invest in human capital to enhance their chances of obtaining an immigrant visa to the destination country. Therefore, this study of the optimal investment in human capital differs from many previous studies. We consider not only the optimal investment in human capital after but also before emigration. This issue is rarely considered because, unless we assume that prospective migrants seek to enhance their chances of obtaining legal admission through investing in human capital, there is no compelling reason to study it. Otherwise our model follows established paths, using the human capital approach to migration introduced by Sjaastad (1962).

Our research is indirectly related to the literature that examines the 'quality' of immigrants (Borjas 1999, 1987; Borjas and Bronars 1991; Chiswick 1999, 1986; Cohen and Zach 1997; Duignan and Gann 1997; Duleep 2000; Lamm and Simpson 2001; Reimers 1998). However, the focus of these studies, which is that the 'new' immigration may be less skilled than earlier immigrations, differs from the focus of our research, which is not concerned with the skills of new, compared to those of earlier, immigrants, but with highly skilled individuals optimally investing in their human capital to gain admission as legal permanent immigrants. Two recent articles by Stark (2003, 2004) and one by Stark *et al.* (1997) start from the same premise, but their focus is the nation's welfare, not the optimal individual investment decision. This article is most closely related to another contribution by Stark *et al.* (1998), which studies the impact of a given probability on human capital investment before emigration; we also look at such investment as a strategic choice to alter the probability of successful emigration but model optimal investment before *and* after emigration. Our more comprehensive approach allows more general conclusions about welfare implications.

The examples and most of the studies cited in this article refer to immigration to the United States, but our model should also be of interest to other countries, particularly those that, like Australia and Canada, give preferential treatment to highly skilled immigrants. The study is also potentially relevant to policy makers in countries seeking to attract highly skilled immigrants but that are less successful than desired, and to countries that are losing highly skilled citizens to emigration (Bouoiyour *et al.*, 2003; Bucovetski, 2003; Carrington and Detragiache, 1999; Chu, 2004; Schwanen, 2000; Straubhaar, 2000).

The Model

Our model is patterned after a model by Djajić and Milbourne (1988), but their article deals with different issues in international migration (guest workers, not permanent immigrants), and we have also extended their model. Chiswick's (1978) research also shares some similarities, but he compares individuals with different educational attainment and job experiences, both natives and immigrants, and obtains estimates of the value of given human capital in the form of schooling and job experience. His cross-sectional study cannot address how immigrants react to incentives to add to their human capital, which is the focus of our study.

Chiswick and Miller (1995, 2001) look at language skills (see also Gonzalez, 2000). Their approach is empirical and they do not study human capital investment as a strategy to successful migration. In addition, learning language skills is but one form of human capital investment. The focus of two other related studies (Borjas, 1987; see also the comments by Jasso and Rosenzweig, 1990, and the response by Borjas, 1990; Chiswick, 1999) is on migrant self-selection and ignores changes in human capital, whereas we are interested in pre-migration and post-migration human capital investments. Duleep and Regets (1999) present a model with a structure similar to ours, but they assume fixed periods, so that they cannot consider the issue of time spent on human capital investment, only intensity and they do not look at optimal human capital investment decisions in anticipation of migration. Earlier relevant models of human capital accumulation include Ben-Porath (1967), Haley (1973), Wallace and Ihnen (1975), and a model of the interaction between human capital accumulation and job mobility by Schaeffer (1985). For the purposes of this paper, we chose a version of the Djajić and Milbourne (1988) model as most appropriate.

The focus of our research makes it necessary to look at pre-migration and post-migration human capital investment. Economic theory suggests that human capital investments are optimally made early in life, usually before entering the labour force. If we further assume that some individuals obtain a high level of education to enhance their chances to obtain a permanent immigrant visa to the destination country of their choice, it becomes clear why we cannot ignore pre-migration human capital investment. Because human capital is rarely fully transferable from one country to another and immigrants benefit if they acquire some of their education and training in the destination country (Borjas, 1994; Chiswick, 1978; Friedberg, 2000; Khan, 1997; Reyes, 1997; Schoeni *et al.*, 1996), we must also study optimal post-migration decisions. Post-migration investing achieves more than just adding to the immigrant's human capital stock; it also increases the value of the initial investment in foreign human capital by validating it. For example, if an immigrant successfully completes an advanced degree at a respected US university, there is no reason to question the quality of the education received in the origin country.

Because we study prospective immigrants who are investing in human capital *before and in anticipation of* emigration and then after having emigrated, we can model their behaviour by using a backward recursive approach. We start with the optimal human capital investment decision after emigration, taking the migrant's human capital and financial assets that she brings with her as given. Following Djajić and Milbourne (1988) we propose a continuous-time model of post-migration behaviours and assume that migrants have an additive utility function that depends only on their consumption of commodities $c_i(t)$ and leisure, $l_i(t)$, in each period, where $i = 1, 2$. The utility function is strictly concave and twice continuously differentiable.

$$U(c_1, c_2, l_1, l_2 \mid \tau) = \int_0^\tau u_1(c_1(t), l_1(t))\mathrm{e}^{-\delta t}\mathrm{d}t + \int_\tau^T u_2(c_2(t), l_2(t))\mathrm{e}^{-\delta t}\mathrm{d}t \quad (1)$$

The subscripts $i = 1, 2$ in $u_i(\cdots)$ denote the utility in period i. The immigrant only works in the second period, which starts at time τ; δ is the discount rate. The combined length of the two periods is fixed at T. An immigrant may find it optimal to start working without any further investment into human capital ($\tau = 0$). In that case the model collapses into a one-period model. The solution $\tau = T$ is of little practical interest. We will show that $\tau = T$ can be an optimal choice only if $l_1 = 1$. This outcome describes a wealthy immigrant who chooses neither to invest in human capital nor to work. If $l_1 < 1$, however, then $\tau = T$ cannot be an optimal solution.

We distinguish between pre-migration human capital, H_f (f stands for 'foreign'), and human capital acquired in the destination country, H. No other distinctions are being made. If it is optimal to invest in post-migration human capital H at all, then the investment will be made immediately after entry, assuming that capital markets are perfect (see Baker and Benjamin, 1997, for a model that relaxes this assumption).

The wage rate is a function of H and H_f. Thus, $w = w\big(H\big(l_1(t), \tau \mid H_f\big) \mid H_f\big)$, where $H\big(l_1(t), \tau \mid H_f\big) = \int_0^\tau (1 - l_1(t))h(H_f)\mathrm{d}t$, and $h(H_f)$ is the rate of human capital accumulation. The rate $h(H_f)$ depends on the stock of foreign human capital only. $(1 - l_I(t))$ measures the time devoted to human capital accumulation. The model does not allow mixing of different forms of human capital accumulation such as formal education first, followed by on-the-job training. The rate of human capital accumulation is therefore either that achieved through formal education and/or training or that obtained through on-the-job training. We assume that $\frac{\mathrm{d}w}{\mathrm{d}H} > 0$, $\frac{\mathrm{d}^2 w}{\mathrm{d}H^2} < 0$ (e.g. Duleep and Regets, 1996; Gonzalez, 2000; Park, 1999), and that H_f is fixed. The monetary cost of acquiring human capital is given by $g(\mathrm{H}_f)$. Immigrants arrive not only with a given stock of human capital, H_f, but also with a given stock of financial assets, A. The size of initial net assets, A, is exogenous to the model and can be positive, zero, or negative. We are now ready to present the immigrant's budget constraint.

$$\begin{aligned}
&\int_0^\tau c_1(t)\mathrm{e}^{-rt}\mathrm{d}t + \int_\tau^T c_2(t)\mathrm{e}^{-rt}\mathrm{d}t + \int_0^\tau (1 - l_1(t))g(H_f)\mathrm{e}^{-rt}\mathrm{d}t \\
&\quad - \int_\tau^T (1 - l_1(t))w\big(H(l_1(t), \tau \mid H_f\big)\mathrm{e}^{-rt}\mathrm{d}t - A = 0 \qquad (2)
\end{aligned}$$

The first two intervals in the budget constraint represent the cost of consumption in period 1 and period 2, respectively. The third part is the monetary cost of human capital investment, and the last part labour income. All costs are expressed in present value, and r is the rate of return on capital. In the following analysis we assume that the discount rate is equal to the rate of return on capital ($\delta = r$). The budget constraint implies perfect credit markets where immigrants can obtain a full loan against future earnings. The consumption good serves as the numeraire.

The immigrant maximizes utility subject to the budget constraint. The Lagrangean for this optimization problem is stated in equation (3). λ is the Lagrange multiplier.

$$
\begin{aligned}
L(c_1, c_2, l_1, l_2, \tau \mid H_f, A, T) \equiv & \int_0^\tau u_1(c_1(t), l_1(t))\mathrm{e}^{-\delta t}\mathrm{d}t + \int_\tau^T u_2(c_2(t), l_2(t))\mathrm{e}^{-\delta t}\mathrm{d}t \\
& - \lambda\Bigg[\int_0^\tau c_1(t)\mathrm{e}^{-\delta t}\mathrm{d}t + \int_\tau^T c_2(t)\mathrm{e}^{-\delta t}\mathrm{d}t \\
& + \int_0^\tau (1 - l_1(t))g(H_f)\mathrm{e}^{-\delta t}\mathrm{d}t \\
& - \int_\tau^T (1 - l_2(t))w\big(H(l_1(t), \tau)) \mid H_f\big)\Bigg]
\end{aligned} \tag{3}
$$

The first-order necessary conditions for an interior optimum follow. For notational convenience, from this point on we omit the arguments of functions except when they are necessary to avoid misunderstandings.

$$\frac{\partial L}{\partial c_1(t)} = \frac{\mathrm{d}u_1}{\mathrm{d}c_1(t)}\mathrm{e}^{-\delta t} - \lambda\mathrm{e}^{-\delta t} = 0 \tag{4}$$

$$\frac{\partial L}{\partial c_2(t)} = \frac{\mathrm{d}u_2}{\mathrm{d}c_2(t)}\mathrm{e}^{-\delta t} - \lambda\mathrm{e}^{-\delta t} = 0 \tag{5}$$

$$\frac{\partial L}{\partial l_1(t)} = \frac{\partial u_1}{\partial l_1(t)}e^{-\delta t} - \lambda\left[-g - (1 - l_2(t))\frac{\partial w}{\partial H}\frac{\partial H}{\partial l_1(t)}\right]\mathrm{e}^{-\delta t} = 0 \tag{6}$$

$$\frac{\partial L}{\partial l_2(t)} = \frac{\partial u_2}{\partial l_2(t)}\mathrm{e}^{-\delta t} - \lambda w\mathrm{e}^{-\delta t} = 0 \tag{7}$$

$$
\begin{aligned}
\frac{\partial L}{\partial \tau} = & \, u_1(c_1(\tau), l_1(\tau))\mathrm{e}^{-\delta\tau} - u_2(c_2(\tau), l_2(\tau))\mathrm{e}^{-\delta\tau} \\
& - \lambda[c_1(\tau) - c_2(\tau) + (1 - l_1(\tau))g + (1 - l_2(\tau))w(H(\tau))]\mathrm{e}^{-\delta t} \\
& + \lambda\frac{\partial w}{\partial H}\frac{\partial H}{\partial \tau}\int_\tau^T (1 - l_2(t))\mathrm{e}^{-\delta t}\mathrm{d}t = 0
\end{aligned} \tag{8}
$$

Finally, the last condition is $\frac{\partial L}{\partial \lambda} = 0$ and this ensures that the optimal solution satisfies the budget constraint (equation (2)).

Equations (4) and (5) yield $\frac{\partial u_1(c_1^*, l_1^*)}{\partial c_1(t)} = \frac{\partial u_2(c_2^*, l_2^*)}{\partial c_2(t)}$: the marginal utility of consumption is the same in both periods. Given the optimal consumption of leisure, this condition determines the optimal allocation of consumption of commodities between the two periods. Since $\delta = r$ and since λ does not depend on t, $c_i(t) = c_i$, $i = 1, 2$. Similarly, equations (6) and (7) imply that $l_i(t) = l_i$. However, equations (6) and (7) show that the marginal utility of leisure is unlikely to be the same in both periods. Therefore, even if the utility function is the same in both periods, the rate of consumption of leisure will generally be different. Because the marginal utility with respect to c_i depends on the consumption of leisure, the rate of consumption of commodities will also generally differ between the two periods.

From equation (5) we obtain $\lambda = \frac{\partial u_2}{\partial c_2}$. Since consumption of leisure and commodities does not depend on t, we rewrite equation (8).

$$u_1 - u_2 = \frac{\partial u_2}{\partial c_2}\left[\underbrace{c_1 + (1 - l_1)g + (1 - l_2)w}_{A} - \underbrace{\left(c_2 + (1 - l_2)\frac{\partial w}{\partial H}\frac{\partial H}{\partial \tau}D(\tau)\right)}_{B}\right] \tag{8a}$$

$D(\tau) = \frac{1 - e^{-\delta(T-\tau)}}{\delta}$. A small increase in τ results in additional expenditures on first-period commodities, human capital investment, and in an opportunity wage loss (term A). On the other hand, consumption expenditures in period 2 decrease and the wage rate increases if τ is extended (term B). Thus, equation (8a) shows that the utility gain from increasing human capital by extending τ by a small amount must be sufficient to compensate for the loss of utility resulting from delaying the start of work. It follows from equation (6) that $(1 - l_2)\frac{\partial w}{\partial H}\frac{\partial H}{\partial(1-l_1)} > g$ is a necessary condition for $l_1 < 1$: the marginal wage gain from increasing $(1 - l_1)$ must exceed the marginal out-of-pocket cost. Equation (7) shows that the second period work effort $(1 - l_2)$ is an increasing function of w, as expected. First-order conditions (FOC) (6) and (7) also show that l_1^* and l_2^* move in the same direction. It is possible that $\tau^* = T$ and we have a corner solution. Of course, this assumes an individual wealthy enough to finance consumption entirely from assets. Since wealthy immigrants are rarely a cause for concern in the destination country, we limit our attention to the case $0 < \tau^* < T$ and $l_2^* < 1$.

Under the assumption that leisure and commodities are normal goods, an increase (decrease) in the size of assets A has a positive (negative) impact on the consumption of leisure and of commodities. That, is $\frac{dc_i^*}{dA} > 0$ and $\frac{dl_i^*}{dA} > 0$, $i = 1, 2$. This is compatible with the conclusion of the previous paragraph that wealthy immigrants may engage in little or no investment in H.

Inelastic Demand for Leisure

Without additional assumptions, the comparative static analysis of the previous model yields only ambiguous results. Therefore, we assume that demand for leisure is inelastic and that $l_1 = l_2 = \bar{l}$. The FOC for this more restrictive version of the model are as follows. For convenience we will not repeat the budget constraint (equation (2)).

$$\frac{\partial L}{\partial c_1(t)} = \frac{\mathrm{d}u_1}{\mathrm{d}c_1(t)}\mathrm{e}^{-\delta t} - \lambda \mathrm{e}^{-\delta t} = 0 \tag{9}$$

$$\frac{\partial L}{\partial c_2(t)} = \frac{\mathrm{d}u_2}{\mathrm{d}c_2(t)}\mathrm{e}^{-\delta t} - \lambda e^{-\delta t} = 0 \tag{10}$$

$$\begin{aligned}\frac{\partial L}{\partial \tau} &= u_1(c_1(\tau))\mathrm{e}^{-\delta\tau} - u_2(c_2(\tau))\mathrm{e}^{-\delta\tau} \\ &\quad - \lambda\big[c_1(\tau) - c_2(\tau) + \big(1-\bar{l}\big)g + \big(1-\bar{l}\big)\big)w(H(\tau))\big]\mathrm{e}^{-\delta t} \\ &\quad + \lambda\frac{\partial w}{\partial H}\frac{\partial H}{\partial \tau}(1-\bar{l})\int_\tau^T \mathrm{e}^{-\delta t}\mathrm{d}t = 0\end{aligned} \tag{11}$$

As before we obtain $\frac{\mathrm{d}u_1}{\mathrm{d}c_1} = \frac{\mathrm{d}u_2}{\mathrm{d}c_2}$. This relationship allows us to express c_1 as a function of c_2, that is, $c_1 = \phi(c_2)$ with $\phi' = \frac{\mathrm{d}c_1}{\mathrm{d}c_2} = \frac{\mathrm{d}^2u_2/\mathrm{d}c_2^2}{\mathrm{d}^2u_1/\mathrm{d}c_1^2} > 0$. Total discounted utility is maximized when we maximize $u_1(\phi(c_2))\int_0^\tau \mathrm{e}^{-\delta t}\mathrm{d}t +$ $u_2(c_2)\int_\tau^T \mathrm{e}^{-\delta t}\mathrm{d}t$, subject to the budget constraint, which is accomplished when we maximize income. Thus, when the labour supply is inelastic the optimization problem reduces to

$$\underset{\{\tau\}}{MAXIMIZE}\left[w(H\,|\,H_f)\int_\tau^T \mathrm{e}^{-\delta t}\mathrm{d}t - g(H_f)\int_0^\tau \mathrm{e}^{-\delta t}\mathrm{d}t\right] \tag{12}$$

H is a function of τ and is, therefore, fixed over in the second period from τ to T. The first-order necessary condition for a maximum is

$$g + w = \frac{\partial w}{\partial H}\frac{\partial H}{\partial \tau}D(\tau) \tag{13}$$

$D(\tau) = \frac{1-e^{-\delta(T-\tau)}}{\delta}$, as before, and we will denote the RHS of equation (13) by $\kappa(\tau)$.

Comparative Static Analysis

Since the comparative static results in the complex case are ambiguous we will limit ourselves to a graphical analysis in the case of inelastic labour supply. Recall that D'$(\tau) < 0$, $D(T) = 0$, w increases with H, and H increases with τ. Therefore, the derivative of $\kappa(\tau)$ is negative and $\kappa(T) = 0$. The slope of the graph of $g + w$ is ambiguous. For small values of H_f, $\frac{\mathrm{d}g}{\mathrm{d}H_f} < 0$ is possible, so that the slope could be negative, but eventually the cost of adding human capital H will stabilize or even increase. Since w is an increasing function of H and t, there will come a point when the opportunity

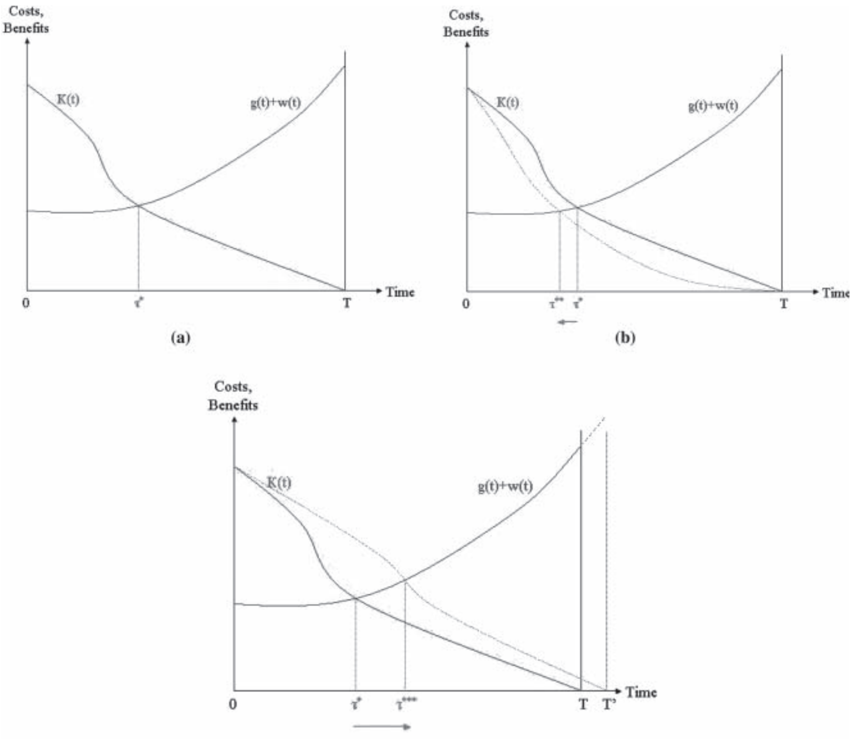

Figure 1. (a) Optimal choice of τ. (b) Effect of an increase in discount rate on optimal choice of τ. (c) Effect of an increase in time horizon T on optimal choice of τ

cost of earnings forgone will begin to dominate and the slope of the graph of $g+w$ will be positive.

Figure 1(a) shows the optimal solution, Figure 1(b) shows how the optimal solution changes if the discount rate changes, and Figure 1(c) shows the effect of a change in T on the optimal solution. The graphs show the expected results that a higher (lower) discount rate discourages (encourages) investments and that a larger (lower) T increases (decreases) the value of investing in H.

Figure 1 demonstrates that it is never optimal to choose the corner solution $\tau = T$, assuming that human capital does not contribute directly to utility, only indirectly through higher earnings. $\tau = 0$ can be optimal if $g+w$ is larger than the marginal benefits of investing in H. This may apply to highly educated immigrants, particularly those from countries with a similar system of higher education and a common language (Baker and Benjamin, 1997), since most of their pre-migration human capital investment should be valued similarly to H. Conversely, because H not only increases the immigrants' stock of human capital (e.g. expressed in 'years of schooling') but also validates their pre-migration human capital, investing in H is particularly attractive for immigrants who are efficient at acquiring (e.g. good knowledge of the language of the destination country) H *and* who brought with them a sizeable stock of foreign human capital whose quality is viewed with uncertainty by prospective employers in the destination country (e.g. immigrants with degrees from 'obscure' foreign universities, particularly those in countries with a significantly different culture and educational system).

The second group of immigrants likely to choose $\tau = 0$ as an optimal solution is almost the exact opposite of the first and consists of those with very little transferable human capital. Because they would have to start almost 'from scratch', it would take them a long time to accumulate a stock of human capital to qualify as highly skilled. Assuming, as we do, that they arrive as adults and not as dependent children, they would have considerably less time left to enjoy the benefits of the investment than do natives and immigrants with significantly more transferable foreign human capital. This group of immigrants is therefore less likely to make large formal human capital investments, everything else being held equal. The disincentive is particularly strong for investing in formal education, but on-the-job training and work experience may serve as (imperfect) alternatives. However, even informal human capital investment strategies depend on language skills, and the lack of such skills is mentioned as the major reason for disadvantages suffered in the labour market by immigrants (e.g. Borjas, 1994; Carliner, 2000; Chiswick and Miller, 1995).

The Timing of Immigration

In our model, the timing of migration is equivalent to answering the question of how much to invest in pre-migration human capital, assuming that permanent emigration to country d is the ultimate objective and, if successful, how much to invest in post-migration human capital. To this end, we re-consider the optimal solution of equation (12) but with assets, A, included. This gives us the total amount available for consumption, which maximizes utility, given H_f, A and τ as shown above.

$$L(\tau, \Gamma) = \left[w(H \mid H_f) \int_{\tau}^{T} e^{-\delta t} dt - g(H_f) \int_{0}^{\tau} e^{-\delta t} dt \right] + A(\Gamma) \qquad \text{(12a)}$$

where Γ is the time spent in the origin country before emigration. Assume that an individual lives Γ' years. Hence, $T = \Gamma' - \Gamma$. Also assume that while living in the origin country, the individual spends all her time investing in H_f. Hence, H_f is completely determined by Γ. Finally, even if the individual cannot successfully emigrate, assume that she will make no additional investments in H_f after time Γ. As we will show below, this is a reasonable assumption. The non-emigrant's discounted earnings from Γ until T are then given by

$$I(\Gamma) = w_f\big(H_f(\Gamma)\big) \int_{\Gamma}^{T} e^{-\delta t} dt + A(\Gamma) \tag{14}$$

The size of assets A is assumed to be negatively related to Γ since, by assumption, the individual spends the time until Γ only investing in human capital. During this time she does not earn an income, but must spend on consumption and the acquisition of H_f. Thus, the derivative $\mathrm{d}A/\mathrm{d}\Gamma < 0$ measures the opportunity cost of acquiring H_f. Finally, assume that the probability of being admitted into the destination country is positively related to H_f, that is, to Γ. We denote this probability $P(\Gamma)$. Our comparative analysis of the optimal post-emigration decisions revealed (see above) that τ is positively related to T and, hence, negatively related to Γ. It is more difficult to determine if τ is positively or negatively related to H_f because we do not know how H_f changes $g(\cdot)$. However, since foreign human capital is a (imperfect) substitute for H, it is reasonable to assume that τ is negatively related to H_f.

Given these assumptions, the individual will choose Γ so as to maximize total expected income after time Γ, given by

$$\Omega(\Gamma) \equiv P(\Gamma) L\big(\tau\big(\Gamma, H_f(\Gamma)\big), H_f(\Gamma), A(\Gamma)\big) + (1 - P(\Gamma)) I\big(\Gamma, H_f(\Gamma), A(\Gamma)\big) \tag{15}$$

Implicit in this formulation is the assumption $L(\cdot) > I(\cdot)$ so that emigration will be chosen if it becomes available. We are able to separate optimizing in the period 0 to Γ from optimizing in the period Γ to T because of the sequential nature of the decision-making, and solve the optimization problem sequentially, going backwards. The FOC for the period 0 to Γ is simple because Γ is the only decision variable.

$$\frac{\mathrm{d}P}{\mathrm{d}\Gamma}(L - I) + P\frac{\mathrm{d}L}{\mathrm{d}\Gamma} + (1 - P)\frac{\mathrm{d}I}{\mathrm{d}\Gamma} = 0 \tag{16}$$

Under the usual assumptions of decreasing returns, the second-order condition for a maximum is satisfied. The first term in equation (16) shows the expected net gain from the increased probability of successful emigration and the sum of the second and third term is the expected net gain from investing in additional H_f.

Implications for the Brain Drain and Migrant Self-selection

Under what conditions will an individual wishing to emigrate, and knowing that H_f is positively related to the probability of successful emigration, acquire more human capital before leaving than an otherwise identical individual who plans to stay? The answer to this question is highly relevant to the study of the brain drain (e.g. Johnson and Regets, 1998). From equations (15) and (16) it follows that an individual who cannot ($P(\Gamma)=0$ for all Γ) or does not wish to emigrate will invest in H_f until $\mathrm{d}I/\mathrm{d}\Gamma=0$. When emigration is possible, then equation (16) shows that investment beyond $\mathrm{d}I/\mathrm{d}\Gamma=0$ may occur because the first term is positive by assumption, which is why unsuccessful candidates for emigration will not add to their stock of H_f after time Γ. Even $\mathrm{d}L/\mathrm{d}\Gamma$ turning negative before $\mathrm{d}I/\mathrm{d}\Gamma$ does not preclude the possibility of investments beyond $\mathrm{d}I/\mathrm{d}\Gamma=0$, as long as $\mathrm{d}P/\mathrm{d}\Gamma$ is sufficiently large and $L \gg I$. If $\mathrm{d}L/\mathrm{d}\Gamma > \mathrm{d}I/\mathrm{d}\Gamma$, $\forall\Gamma$, then individuals who plan to emigrate will acquire more human capital than otherwise identical individuals who prefer to stay, for any value of $P(\Gamma)$.

This reveals the possibility of self-selection of immigrants that 'looks the same' as that described by Borjas (1987), but is in fact different. Positive self-selection in Borjas (1987) describes those emigrants who *are* among the highly educated citizens of their native country. Our analysis shows that it is possible that those wishing to emigrate have an incentive to *become* more highly educated. Stark (2004) reaches the same conclusion.

Our analysis also shows that a policy by more advanced countries favouring highly educated applicants for the award of permanent resident visas (expressed by $\mathrm{d}P/\mathrm{d}\Gamma > 0$) may increase the cost associated with the loss of highly skilled citizens suffered by less advanced countries. This occurs because it strengthens the incentive of would-be emigrants to invest in H_f beyond what would be optimal were the individual to stay. Thus, the sending country's loss is greater than in the absence of the policy. Equation (16) shows that the economically most disadvantaged countries (large difference between L and I) incur the largest relative losses, because of the positive relationship between the difference $L(\cdot) - I(\cdot)$ and overinvestment in H_f. If those left behind suffer negative externalities from the loss of educated citizens, the welfare loss to the sending country will be even greater.

In contrast to the above argument, Stark (2004) argues that the positive relationship between the probability of successful emigration and H_f may result in a welfare gain in the origin country. This conclusion depends on the assumption that there are positive externalities to education, which result in underinvestment in human capital relative to what is socially optimal. It is possible, however, that highly subsidized education offered in many countries (e.g. German universities do not charge tuition), is already working to better align private choices with social benefits.

Our analysis shows that the failed would-be emigrant suffers a welfare loss resulting from the overinvestment in H_f, but the effect on the social welfare of the origin country as a whole depends on the aggregate impact. It is correct that $\mathrm{d}P/\mathrm{d}\Gamma > 0$ has a positive impact on general educational attainment in the origin country, which might increase social welfare if education yields positive externalities, as assumed by Stark (2004). However, because $\mathrm{d}P/\mathrm{d}\Gamma > 0$ encourages additional investments in education, it also increases the welfare loss associated with each successful emigrant. Therefore, even if education yields positive externalities, the percentage of would-be emigrants who fail to realize their ambition must be sufficiently large to compensate for the welfare reduction resulting from the loss of those who succeeded.

If $P(\Gamma) = 1$ for all Γ, then the optimality condition is $\mathrm{d}L/\mathrm{d}\Gamma = 0$. Whether this implies a larger, the same, or a smaller investment in H_f than that of non-migrants, depends on the net marginal benefit in the origin and destination country, respectively, of acquiring more H_f. As shown above, if $\mathrm{d}L/\mathrm{d}\Gamma > \mathrm{d}I/\mathrm{d}\Gamma$, then 'overinvestment' in the sense described above occurs. If the marginal net value of adding to H_f is valued equally in both countries ($\mathrm{d}L/\mathrm{d}\Gamma = \mathrm{d}I/\mathrm{d}\Gamma$), then there is no difference between emigrants and stayers. Finally, if the marginal net value of H_f is higher in the origin than in the destination country, the emigrants will be less skilled than identical citizens who wish to stay. In Borjas' (1987) analysis this would show up as negative migrant self-selection, but is really only a reflection of the relative costs and benefits of investing in human capital in the destination versus the origin country. This finding suggests that to truly understand whether the new immigration is less skilled than the old, we have to look at immigrants not at the time of entry, but a few years later, after they had time to adjust their human capital stock. Furthermore, the analysis suggests that we should be able to observe systematic differences in immigrants' initial human capital stock by origin country. $P(\Gamma) < 1$ and $\mathrm{d}P/\mathrm{d}\Gamma > 0$ weaken this relationship because they create an incentive to invest in more H_f than would otherwise be the case.

To more fully understand the costs and gains of investing in H_f, we present the expanded version of equation (16).

$$\underbrace{\frac{dP}{d\Gamma}(L-I)}_{+} + P\left[\underbrace{\frac{\partial L}{\partial \Gamma}}_{-} + \underbrace{\frac{\partial L}{\partial \tau}\frac{d\tau}{d\Gamma}}_{-} + \underbrace{\frac{\partial L}{\partial H_f}\frac{dH_f}{d\Gamma}}_{+} + \underbrace{\frac{\partial L}{\partial A}\frac{dA}{d\Gamma}}_{-}\right]$$
$$+ (1-P)\left[\underbrace{\frac{\partial I}{\partial \Gamma}}_{-} + \underbrace{\frac{\partial I}{\partial H_f}\frac{dH_f}{d\Gamma}}_{+} + \underbrace{\frac{\partial I}{\partial A}\frac{dA}{d\Gamma}}_{-}\right] = 0 \qquad (16a)$$

In each of the two terms in brackets, the negative signs signal aspects of the marginal costs of further investments into H_f, and the positive terms the marginal gains. The costs consist of the reduction of the length of the period available after investing in H_f has stopped and the reduction in assets A as more of them are used up to finance H_f. In the case of the emigrant, there is also the reduction in τ, the optimal time available to invest in H. In both cases, staying and emigration, the gains consist of enhanced earning power.

Finally, if $P < 1$, then an added benefit is the enhanced probability of successful emigration.

If H_f is a close substitute of H, and if the costs of acquiring H_f are small relative to the cost of acquiring H, then the sum $\left[\underbrace{\frac{\partial I}{\partial \Gamma}}_{-} + \underbrace{\frac{\partial I}{\partial H_f}\frac{dH_f}{d\Gamma}}_{+} + \underbrace{\frac{\partial I}{\partial A}\frac{dA}{d\Gamma}}_{-}\right]$ in equation (16a) will stay positive longer than otherwise. In such a case, most if not all human capital investment will take place in the origin country, regardless of the value of $P(\Gamma)$. To discourage citizens from obtaining an advanced education and then leave, governments could make students bear the costs of their education rather than subsidizing it. Considerations other than aversion to the loss of highly educated citizens may recommend against such a policy, however. A country could also reduce losses by not offering advanced studies, an approach that may make sense if there are few domestic opportunities for individuals with such skills. For such skills, it may be more cost effective to encourage study abroad, even if this increases the risks of 'losing' skilled natives to other countries.

Human Capital of Immigrants versus that of Natives

Assume that natives and immigrants have the same life expectancy and inherit the same assets: they are identical except for their initial location. Natives acquire all of their human capital in country d. Immigrants acquire a pre-migration human capital stock H_f and spend time τ in the host country accumulating additional human capital H after immigrating. We assume that pre-migration human capital is at most of equal value to human capital acquired in country d: $w(H(\bar{t}), 0) \geq w\big(0, H_f(\bar{t})\big)$ for a given $\bar{t} > 0$. Then the earnings forgone while investing in (post-migration) human capital are smaller for immigrants than for natives, and the former will therefore spend more total time (pre-migration and post-migration, combined) on acquiring human capital than otherwise identical natives. The additional time will not result in higher wages than those of natives, however, because it will generally not be optimal to spend the time required to completely make up for the lower value of H_f compared to H. This result is compatible with the findings of Reyes (1997), and Schoeni *et al.* (1996).

Conclusions

Noting the significant and growing number of highly skilled permanent immigrants to the United States who initially come as students or post-doctoral scholars (National Science Foundation, 1996, 1998), we present a theoretical model of the human capital investment decision before and after emigration. The results of the analysis suggest that the two groups least likely to make an additional investment are almost the exact opposites of each other. Well-educated immigrants from countries with an educational system that is similar to, and/or respected in, the destination country, can transfer almost all of the human capital acquired in their native country. For them, the incentive to add to it is therefore relatively small. Immigrants with a low stock of human capital and coming from a country with a different educational system will also tend to make small, if any, additional human capital investments. Unlike the members of the first group, however, it is not because more human capital would not increase their earnings by very much but because their opportunity cost is very high. In both cases, the net benefit of investing in post-migration human capital is low.

A second important conclusion relates to how we regard the issue of self-selectivity as it applies to the so-called brain drain. By analysing pre-migration and post-migration human capital investments, we show that the possibility of emigration may encourage individuals to invest more in H_f than they might do otherwise. This outcome seems likely if H_f is positively related to the probability of gaining permanent residency status in the desired destination country, but can occur otherwise, as well. This sheds a somewhat different light on the brain drain issue, particularly its cost to the origin country. In the absence of positive externalities, assumed to exist by Stark (2004), such overinvestment results in a welfare loss in the origin country, even if the emigration attempt is not successful. If H_f has no impact on the probability of successful emigration, individuals may still end up investing more in H_f than otherwise identical individuals not wishing to emigrate.

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Note

[1] SandE = scientists and engineers.

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