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Human Capital Flight: Impact of Migration on Income and Growth

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Abstract

This paper analyses the impact of government tax and subsidy policy on immigration of human capital and the effect of such immigration on growth and incomes. In the context of a two-country endogenous growth model with heterogeneous agents and human capital accumulation, we argue that human capital flight or "brain drain" arising out of wage differentials, say because of differences in income tax rates or technology, can bring about a reduction in the steady state growth rate of the country of emigration. Additionally, permanent difference in the growth rates as well as incomes between the two countries can occur making convergence unlikely. While in a closed economy, tax-financed increases in subsidy to education can have a positive effect on growth, such a policy can have a negative effect on growth when human capital flight is taking place. Since subsidizing higher education is more likely to induce substantial brain drain, it is likely to be inferior to subsidy to lower levels of education if growth is to be increased.

JEL Classification Numbers:

015, 040, H20

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Contents

Summary

This paper examines the impact of the migration of human capital on the growth and levels of incomes in the context of an endogenous growth model. A two-country endogenous growth model with heterogeneous agents is used to study the impact on growth and incomes of migration of human capital that could arise from wage differentials. The paper shows that wage differentials can truncate the distribution of talent in the country of emigration in the presence of migration and assimilation costs. The after-tax wage differential between the home and the foreign country determines where the domestic human capital distribution will be truncated: the higher the tax differential, the lower the point of truncation. This point of truncation is reduced with decreases in migration and assimilation costs, as well as with increases in average levels of education in the home country.

It can be shown that "brain drain" reduces the growth rate of the effective human capital that remains in the economy and, hence, generates a permanent reduction of per capita income growth in the home country. Brain drain also can induce an increase in the growth rate of the country to which migration has taken place although the effect can vary over time, depending on the evolution of the ratio between the average human capital in the two countries. The paper also shows that migration of human capital can lead in the long run to differences in both the growth rates and the levels of per capita incomes across countries. The magnitude of the adverse impact of the brain drain depends on the contribution of the quality of differing levels of human capital in the production process. Unfortunately, this is an area on which little theoretical work has been done, and for which it is extremely difficult to develop empirical evidence.

The paper also analyzes the impact of policies aimed at fostering human capital accumulation by subsidizing education. In a closed economy, a tax-financed increase in education subsidy that preserves the fiscal balance will induce a positive growth effect while, in an open economy (where labor is mobile), such a policy can have a negative impact on growth because migration takes place beyond a particular education level. The optimal policy should take this information into account and, in the presence of migration, allow the subsidy to increase with the education effort up to this level of education.

The analysis presented in this paper has important implications for economic policy in developing countries. For example, demand management, which is an important element of adjustment programs, is frequently achieved by a combination of increased taxes and wage restraints. To the extent that ability is an important determinant of growth, the design of adjustment programs should be concerned with the consequences of such policies for migration.

I. Introduction

Human capital has long been considered to be an important determinant of economic growth (Schultz (1971, 1981)). Recent research has further reinforced this role of human capital emphasizing it as a significant explanatory variable for explaining differing growth experiences of countries (e.g., Lucas (1988), Stokey (1991) and Barro and Lee (1993)). Despite this recognition of the important role for human capital, the international movement of such capital has not generated the same interest in recent years as has that of its counterpart factor of production--physical capital. The flight of physical capital has been analyzed in a number of studies in recent years and has been recognized as a constraining factor for domestic growth (e.g., Khan and Haque (1985) and Schineller (1994)). Such flight is hypothesized to result from differing risk perceptions associated with domestic and foreign investments which serves to drive a wedge in any expectations of a parity of returns. 1/

In a commensurate manner, the flight of human capital or the migration of the more skilled could also occur as a result of higher rates of return for work in the foreign country than at home. Such differences in rates of return may arise because of differences in government policies and persist even if certain preference for staying at home is taken into account. 2/ In this paper we examine the impact of migration of human capital on the growth and levels of incomes in the context of an endogenous growth model. Further, we identify the influence of tax policy and other variables on such migration and economic growth. 3/ We are also able to determine how this migration may lead to not only sustained differences in income levels but also in growth rate between countries.

This issue received a fair amount of attention under the nomenclature of the "brain drain" in the seventies. In a neoclassical approach where each individual obtains and consumes his marginal product, the emigration of the more skilled workers in response to economic incentives increases world income without reducing the welfare of those left behind; migrants earnings are improved while the welfare of those who have been left behind is not reduced (see Grubel and Scott (1966) and Johnson (1967)). Bhagwati and Hamada (1974) pointed out that there could also be a possibility of a loss

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1/ Khan and Haque (1985) develop such a model that explains capital flight in these terms. See Cuddington (1986) for some empirical evidence on the determinants of capital flight.

2/ The higher rate of return or wage rate could be calculated adjusting for an equalizing difference for a preference for location in home country.

3/ Recent endogenous growth models suggest that government tax policy can affect long-run growth rates. Among them are Lucas (1990), King and Rebelo (1990), Kim (1992), Jones, Manuelli and Rossi (1993), Rebelo and Stokey (1993) and Cashin (1994). However, these models are restricted within a closed economy model, which cannot allow for the effects of taxes on economic growth through inducing brain drain.

of welfare of the non-migrants as a result of migration if there are externalities associated with migration such as those that would arise out of a loss of the scarce skills. To deal with this externality, Bhagwati (1972) recommended a "brain drain" tax. 1/ The proposed tax was to be levied on the highly educated migrants only and collected by the country of migration for a period of say 10 years. The revenues from such a tax which were estimated to be about US$ 750 million in 1972, were to be made available to the UN for use in its financing of development. As is obvious, despite the academic interest in it, the tax proposal was never seriously considered for implementation despite these impressive revenue estimates.

The role of human capital has received renewed attention in recent research on endogenous growth. These models of growth have endogenized growth by allowing for increasing or constant returns to scale, which results from human capital accumulation by individuals. 2/ In this new approach, the impact of migration of human capital may have significant implications for domestic incomes and economic growth. Such flows of human capital may be one of the factors that explain differences in growth rates across countries. 3/

In view of this increasing importance of the role of human capital, this paper revisits the issue of "brain drain" in the context of the newer endogenous growth approaches. The paper presents a dynamic general equilibrium model with two period overlapping generations and heterogeneous agents. 4/ In each of the countries, growth is driven by the accumulation of human capital by economic agents. The technology for human capital accumulation is linear, which allows for endogenous growth. Agents live for two periods, spending part of their youth gaining an education to improve their earnings in the second period. In addition, agents in the model are endowed with differing abilities, and consequently they also differ in their optimal human capital accumulation and other decisions.

To capture the effects of migration and government policies on growth, we use this model for two countries that are identical except for government policies and possibly technology. Having gained an education in the first

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1/ This proposal received very serious attention among academics in the mid seventies. A major conference was held on the issue of instituting a tax on the brain drain in Bellagio in 1975. The proceedings of this conference are published in Bhagwati and Partington (1976) and Bhagwati (1976).

2/ See, for example, Lucas (1988), Stokey (1991), Rebelo (1991), and King and Rebelo (1990).

3/ Such flows of human capital may also affect the speed of convergence of per-capita incomes among the economies of the world. See Barro and Sala-i-Martin (1994), chapter 9.

4/ See also De Gregorio and Kim (1994) who use this type of model to study the effects of credit markets on education, income distribution and growth.

period, individuals choose whether they will continue to live in their own country in the second period of their lives or migrate to the foreign country. The two countries have differing tax policies or technology which means that after-tax wage differentials prevail between them. We use tax differentials to capture any number of government imposed restrictions--from incomes policy to government monopsonistic or price leadership positions--on the domestic wage rates. 1/ Migration takes advantage of this after-tax wage differential and contends with costs associated with it and with assimilation in the foreign country. Individual education and consumption decisions as well as the choice of residence in old age are thus taken jointly to maximize the utility over the two-period lifetime.

The model shows that in the case where the after-tax rate of return in foreign country is higher and migration and assimilation costs are in some intermediate range, individuals with higher learning abilities will choose to work abroad, while those with less abilities will stay at home. The intuition for the migration of the highly-educated individuals is as follows. The cost of immigration, which is fixed cost of migration, is constant regardless of abilities. However, the gain from immigration increases with abilities. Hence for the more able, the increase in return on their human capital when moving to the foreign country is more than enough to compensate the fixed cost of migration. For the less skilled, however, it is reversed.

We also examine the effect of brain drain on the rates of growth of the two countries. We show that human capital flight generates a permanent reduction of per capita income growth rate in the country of emigration, and that the effect of brain drain on the growth in the country of immigration varies over time with the evolution of the ratio of the average level of human capital in the two countries. Further, we illustrate that human capital flight can generate a difference in growth rates as well as level of incomes across countries.

Finally, we examine the effect of alternate tax and subsidy policies on economic growth in the presence of brain drain. We first show that in the absence of migration, a tax-financed increase in education subsidy that preserves the fiscal balance, will induce a positive growth effect, while in the presence of human capital flight such a policy can have a negative impact on growth. In addition, we show that a replacement of subsidies on higher levels of education by those on lower levels will increase the growth rate keeping the spending constant. The intuition behind this is clear. Increases in subsidies on higher levels will increase the education of the more able. They are more likely to migrate and hence make little

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1/ See Bhagwati (1976) and Bhagwati and Partington (1976) for evidence on wage differentials between the domestic country and the country of migration as well as some description of government intervention in developing country labor markets.

contribution to the income growth of the country while they impose a burden on the government budget.

The rest of the paper is divided into five sections that are followed by a conclusion. The next section presents the model. Section III analyses the consumption, human capital accumulation, and migration decisions of the agents in the model. Section IV examines the growth consequences of migration or human capital flight and is followed by a section that analyses the effects of taxes and subsidies on brain drain and economic growth. Section VI discusses some extensions and the paper ends with a conclusion.

II. The Model

1. Consumers

This section presents a two-country endogenous growth model with heterogeneous agents. The model world consists of two countries which are identical in everything except government policies such as wage tax, education subsidies and immigration policy and possibly technology. In each country, the same number of heterogeneous agents, who live two periods, are born every period. There is no population growth and without labor mobility, each of the two countries is populated with the same number of heterogeneous agents. We assume that each agent maximizes the following two-period utility function:

$$U(c_{t,t}, c_{t,t+1}) = u(c_{t,t}) + \beta u(c_{t,t+1}), \tag{1}$$

where $c_{t,\tau}$ is consumption during period τ of an individual born at period t and β is the subjective discount factor. For simplicity, we assume that the momentary utility function takes the logarithmic form:

$$u(c_{t,\tau}) = \log c_{t,\tau}. \tag{2}$$

In each country, a certain number of agents are assumed to be born at time t with the same level of human capital, h_t, which can be different across countries. They are endowed with one unit of non-leisure time in each period of their life. We assume that when they are young, they cannot move to the foreign country for either work or study. When young, each agent can invest in human capital in his home country, by devoting v^j unit of time to education, which is provided free of charge. Education activity for the young is subsidized by the government. Education subsidy is assumed to increase with the average human capital over time as $E_t = \alpha\ h_t$ where α is the subsidy ratio. 1/ As is described below the subsidy is financed by a tax on labor incomes of the population. Consequently, agents' income is derived from after-tax labor income proportional to his time spent on labor, $(1-v^j)$ and education subsidies. When young, the j-th individual faces a budget constraint of the form:

$$c_{t,t} = (1-\tau_d)w_t(1-v^j)h_t + \alpha h_t, \tag{3}$$

where τ_d is the rate of wage tax in home country and w_t is the domestic real wage rate at time t. 2/ A similar budget constraint with an income tax rate of τ_f prevails in the foreign country.

Two types of education subsidy policies which are often found in practice are considered in this model. We consider a proportional subsidy that increases with the time spent on education. We also consider a subsidy that is independent of amount of time spent on education. Therefore, subsidy can be expressed as a sum of the two different types--proportional and lump-sum--as $\alpha = av^j + c$ where a is the rate of proportional subsidy, i.e., it increases with the time spent on education, while c represents a lump-sum subsidy to all individuals. Consequently, the latter subsidy decreases with the time spent on education such that lower levels of education gets a higher rate of subsidy than higher levels. The corresponding budget constraint can be written as:

$$c_{t,t} = (1-\tau_d)w_t(1-v^j)h_t + (av^j+c)h_t. \tag{4}$$

When old, the agent is allowed to work in either his home or foreign country. However, for a given work effort agents who work in foreign country cannot work at their full capacity they would have at home, because of difficulties stemming from assimilation such as differences in languages and cultures. The effective labor of agents who work abroad is written as follows:

1/ This specification of subsidies for growing economies is fairly flexible. If education subsidies are not growing as fast as human capital and output, they will be negligible in the long-run. The steady state for such case of slow growing subsidies is considered as the case where α is equal to zero.

2/ The subscripts "d" and "f" will be used to denote "home: and foreign country variables respectively.

$$h^{f,j}_{t+1} = q\, h^{j}_{t+1}. \qquad (5)$$

Here $h^{f,j}{}_{t+1}$ is the effective labor of an agent who works abroad, and $q \in (0,1)$ is the assimilation parameter representing how similar one's mother tongue, native culture, etc. are to the foreign country and how friendly the natives in that country are to foreigners. 1/

Because of immigration policy, costs of transportation, and dislocation, we assume that migration incurs a fixed cost, T_t, regardless of the abilities of agents at time t. 2/ In addition, we assume that the fixed cost varies over time proportionally to the average human capital as: $T_t = \gamma h_t$ where γ is the fixed cost ratio. This assumption appears relevant because migration and search for a job in new environment takes time and foregone wages for the migration period is proportional to the level of human capital. 3/

An old agent derives his income net of tax from supply of effective labor at home or abroad, and spends all of it on consumption.

$$c_{t,t+1} = (1-\tau_d) w_{t+1} h^{j}_{t+1} l^{j}_{d} + ((1-\tau_f) w^{f}_{t+1} q h^{j}_{t+1} - \gamma h_t) l^{j}_{f}, \qquad (6)$$

where l_d is the labor supply in home country which is zero or one, τ_f is the income tax rate in foreign country, $w^{f}{}_{t+1}$ is the real wage rate in foreign country, and l_f is the labor supply in foreign country.

For simplicity, we assume that there is no financial market. Although individuals cannot hold financial assets, they will engage in intertemporal smoothing by adjusting time devoted to human capital accumulation. It is

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1/ Of course, there might be some rare people who are more productive in foreign countries than at home and whose q is greater than one. However, even an allowance of q greater than one does not change our main results.

2/ We could assume that the transaction cost varies inversely with the skill level of agents. This might reflect that the more smart people can adjust to new environment with less costs or that some countries admit people with higher skills more readily than with lower skills. However, such modification does not change the main results on the growth effects of brain drain, although it will affect the path of transitional dynamics.

3/ Instead we could assume the fixed cost is constant over time. Then in growing economies, the magnitude of the effect of fixed cost on the migration decision will decrease over time. Hence, the analysis for the steady state where the fixed cost converges to zero is the same as the case of zero fixed cost studied in the next section.

assumed that human capital accumulation for individual j is a linear function of time spent on formal education, v^j, as follows:

$$h_{t+1}^{j} - h_t = \delta^j v^j h_t, \tag{7}$$

where δ^j represents how efficiently agent j produces human capital.

We assume that the human capital level with which all individuals are born, h_t, is equal to the average level of skills of their parents' generation, $h_t{}^e$. Therefore, there is an *intergenerational externality*, by which human capital of parents' generation is transferred to their children. Without intergenerational externality, the positive growth cannot be achieved. At the individual level, however, parents cannot increase by themselves their offsprings' level of skills.

A distinguishing feature of this model is that each agent has different education ability. However, the distribution of education ability is identical across countries. For simplicity, it is assumed that in both countries, human capital efficiency parameter δ^j is non-negative and uniformly distributed among continuum of individuals indexed by $j \in (0,1)$ in each cohort as follows:

$$\delta^j = bj + (m - \frac{b}{2}). \tag{8}$$

Here b reflects the degree of the difference in education abilities across agents and m is the average level of education efficiency of the economy. Indeed, given the distributional assumption on j, the random variable δ^j is uniformly distributed in the interval $[m-b/2,\ m+b/2]$, with an average of m and variance of $b^2/12$.

2. Firms and wage determination

On firm side, a constant returns to scale production function of effective labor is assumed as follows:

$$y_t = Ah_t, \tag{9}$$

where h_t represents effective unit of labor employed, and A is the marginal product of effective labor.

Firms choose optimal effective labor to maximize the firm value, taking prices as given. The firm's first-order condition for optimal employment is:

$$A = w_t, \tag{10}$$

which implies before-tax wage rates are constant over time and identical across countries.

We allow the possibiity that the marginal product of effective labor varies across countries and hence firms in both countries operate under different technologies. In particular, the difference in labor productivity can persist when there exists some technology which is hard to be transferred across border. For simplicity, we assume that $A^f = \lambda A$ where A^f and A represents the marginal product of labor in foreign and home country respectively, and λ captures the relative level of technologies. 1/

3. The government

In our model, the government only collects taxes to distribute the education subsidy. The government budget constraint in each of the two countries if no migration takes place is therefore:

$$\int_0^1 \tau_i [w_t(1-v^j)h_t + w_t(1+\delta^j v^j)h_{t-1}]dj = \int_0^1 (av^j h_t + ch_t)dj \ ; \ i = d,f() \tag{11}$$

III. Household Decisions: Consumption, Human Capital Accumulation and Migration

Agents in both countries choose the level of their investment in education when young and the location of their residence when old to maximize utility over their lifetime. In our setup where there are no credit markets, individuals attain the optimal inter-temporal consumption smoothing only through the accumulation of education. 2/ With an

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1/ In order to highlight the effects of differential tax/wage policies, we might make a more specific assumption that firms in both countries operate under identical technologies (i.e., $\lambda = 1$). Under this assumption of no technology gap, differential government policies alone generate the main results of this paper including the effects of brain drain on growth.

2/ See De Gregorio and Kim (1994) for a discussion of the role of credit markets in such a model. Allowing domestic credit markets to operate will not change the results of this paper substantially.

introduction of migration, however, their optimal education investment depends on the location of their residence when old, since the after tax return on investment in human capital varies with country of residence. Thus, individuals will locate themselves according to where the highest level of utility is attained, after comparing the level of utility which depends on the education investment, which in turn depends on the location of residence.

To discuss more formally the optimal choice of education and residence, we first consider the optimal choice of education given the location of residence. To see this we can combine equation (4) and (6) and use the equation for human capital accumulation, (7), to obtain the following intertemporal budget constraint:

$$[(1-\tau_d)w_t(1-v^j) + (av^j+c)]\, c_{t,t+1}$$
$$= [w_{t+1}(1+\delta^j v^j)\,((1-\tau_d)l_d^j+(1-\tau_f)q\lambda l_f^j) - \gamma l_f^j]\, c_{t,t}, \tag{12}$$

which depends on the location of residence. Note that in particular, whether migration incurs the fixed cost or not depends on the decision to migrate.

Under the budget constraint, the agent chooses consumption and educational investment to maximize utility, taking prices and location to live as given. Under the assumption of interior solutions, the first-order condition of agent j takes the following form:

$$u'(c_{t,t})[(1-\tau_d)w_t - a] = u'(c_{t,t+1})[\beta\delta^j\, w_{t+1}((1-\tau_d)l_d^j+(1-\tau_f)q\lambda l_f^j)], \tag{13}$$

which under the assumption of logarithmic utility function, implies

$$\frac{c_{t,t+1}}{c_{t,t}} = \beta\delta^j w_{t+1}\, \frac{(1-\tau_d)l_d^j+(1-\tau_f)q\lambda l_f^j}{(1-\tau_d)w_t - a}. \tag{14}$$

This indicates that the after-tax rate of return and relative consumptions depend on the location of residence in the second period of life.

Solving the consumer's problem, the optimal choice of education investment and consumptions for each agent can be expressed as a function of location of residence. Using the first-order conditions and budget constraint, the optimal choice of time allocation on education can be calculated as follows:

$$v^j = \frac{\beta H}{(1+\beta)} - \frac{1 - \gamma l_f/w_{t+1}M}{(1+\beta)\delta^j}, \tag{15}$$

and the optimal consumption path as:

$$c_{t,t} = (1-\tau_d)\, w_t h_t \left[\frac{1 + \delta^j + (\delta^j c-a)/(1-\tau_d)w_t - (\gamma/q\lambda)Y\, l_f^j}{(1+\beta)\delta^j}\right], \tag{16}$$

$$c_{t,t+1} = M\, w_{t+1} h_t\, \beta \left[\frac{1 + \delta^j + (\delta^j c-a)/(1-\tau_d)w_t - (\gamma/q\lambda)Y\, l_f^j}{(1+\beta)\ (1-a/(1-\tau_d)w_t)}\right], \tag{17}$$

where $H = ((1-\tau_d)w_t + c)/((1-\tau_d)w_t - a)$, $M = (1-\tau_d)l_d{}^j + (1-\tau_f)q\lambda l_f{}^j$, and $Y = (1-a/(1-\tau_d)w_t)\ (1/w_{t+1}(1-\tau_f))$.

The above solutions indicate that the optimal education investment and consumptions for each agent are function of $l_d{}^j$ and $l_f{}^j$, the location of residence. For example, an agent would invest more heavily in the accumulation of human capital when he migrates than when he stays at home, since v^j evaluated at $l_f{}^j = 1$ is greater than at $l_f{}^j = 0$. 1/ Then it follows that the indirect utility is a function of location of residence.

As a final step to solve the consumer's problem, we consider the optimal residence choice given the utility derived as a function of

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1/ In this heterogeneous agent model, the optimal choice of education investment of each individual depends on his ability as well as his residence when old. In particular, the more able agents spend more time on education, as can be easily shown by $\partial v^j/\partial \delta^j > 0$.

residence. Whether an agent migrates or not affects his education investment and consumption path, and hence the corresponding utility. An agent's utility when he works at home, U_d, and his utility when he migrates and works in foreign country, U_f, will be calculated as:

$$U^d = \log[(1-\tau_d)^\beta(1 + \delta^j + (\delta^j c-a)/(1-\tau_d)w_t)^{(1+\beta)}N], \tag{18}$$

$$U^f = \log[(1-\tau_f)^\beta q^\beta \lambda^\beta(1 + \delta^j + (\delta^j c-a)/(1-\tau_d)w_t - (\gamma/q\lambda)Y)^{(1+\beta)}N], \tag{19}$$

where $N = (1-\tau_d)(w_t w_{t+1}{}^\beta)h_t{}^{(1+\beta)}(1/(1+\beta)\delta^j)(\beta/(1+\beta))^\beta(1-a/(1-\tau_d)w_t)^{-\beta}$.

Depending on the relative level of utilities, U^d and U^f, the optimal solution for the residence of the old will be $1_d{}^j = 0$ or 1 ($1_f{}^j = 1$ or 0). Since U^d and U^f depend on the abilities of each agents, the optimal choice of residence can vary across agents. Figure 1, 2 and 3 illustrate how the utilities and the optimal location of residence change depending on the level of the abilities. Since the level of U^d and U^f depend not only on abilities of each individual but also on wage tax rates, education subsidy rates, fixed cost of immigration and language similarity, the optimal choice of residence depends on these parameters as well.

Depending on these parameters, there are three distinct cases. First, consider a case where all agents choose to work at home. This is the case where the after-tax rate of return in foreign country after adjusting assimilation costs is lower than that of home country (i.e., $(1-\tau^f)q\lambda < (1-\tau^d)$), or the fixed cost of migration, γ goes to infinity, or assimilation parameter q or relative level of foreign technology λ is close to zero. In this case, it is obvious from a comparison of (18) and (19) that U^d is greater than U^f for all agents. Hence in this case, all individuals choose to work at home. This is illustrated in Figure 1. In particular, the case of infinite γ represents that of labor immobility and, therefore allows the government to maintain any wage/tax/subsidy policy at home that it chooses.

Alternatively, consider the opposite case, where all agents move to the foreign country when old. If the after-tax rate of return in foreign country is higher and $\gamma = 0$ (i.e., no fixed costs), U^f is greater than

U^d for all j, as illustrated in Figure 2. 1/ This case of zero γ represents a polar extreme with perfect labor mobility where there are no costs of migration, in that case any tax differentials after adjusting assimilation costs and technology gaps will result in the entire population of the country with the higher tax rate (in this case the domestic economy) migrating to the one with the lower tax rate.

The third and most interesting case is the intermediate one where some move to the foreign country and others remain at home as illustrated in Figure 3. This is the case where the after-tax rate of return in foreign country is higher and the parameters γ, q and λ are in some intermediate range. For this case, the following proposition can be established.

Proposition 1: If $(1-\tau^f)q\lambda > (1-\tau^d)$, and γ, q and λ are within some intermediate range, there exists an individual j^* with ability δ^*, who is indifferent between staying and migrating, and belongs $0<j<1$. Furthermore, individuals with higher learning abilities than j^* will choose to work abroad, while those with less abilities will stay at home.

Proof: For some intermediate range for the parameters γ, q and λ, and $(1-\tau^f)q\lambda > (1-\tau^d)$, it holds that $U^d > U^f$ at j=0 and $U^d < U^f$ at j =1. In addition, it can be shown that U^d and U^f are monotonic functions of j. Hence there exists an individual in the margin, j^* who belongs to $0<j<1$ and for whom the value of U^d is equal to U^f.

Further, in this case, it can be easily shown that the slope of U^d is greater than that of U^f. Then it follows that for $j<j^*$, $U^d > U^f$ and for $j>j^*$, $U^d < U^f$. ‖

The intuition behind the proposition of the human capital flight or the migration of the highly-educated individuals is as follows. The cost of emigration, which is fixed cost of migration, is constant regardless of abilities. However, the gain from emigration increases with abilities. Since wages are measured in effective units, earnings vary directly in relation to individual human capital levels, which increase with abilities. Hence for the more able, the increase in return on their human capital when moving to the foreign country, after adjusting for taxes, technology and assimilation costs, is more than enough to compensate the fixed cost of migration. On the other hand, the less skilled or educated cannot earn enough to be able to make up the fixed cost of migration and hence find that they are better off remaining at home.

We discuss more the j^*-th individual whose utility derived from staying at home or working abroad is the same. All individuals with abilities above

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1/ The emigration of the whole population can take place even though γ is not zero, as far as the fixed cost of migration is small enough, compared to the difference between after tax return in foreign country and home country.

Figure 1. Case of No Migration

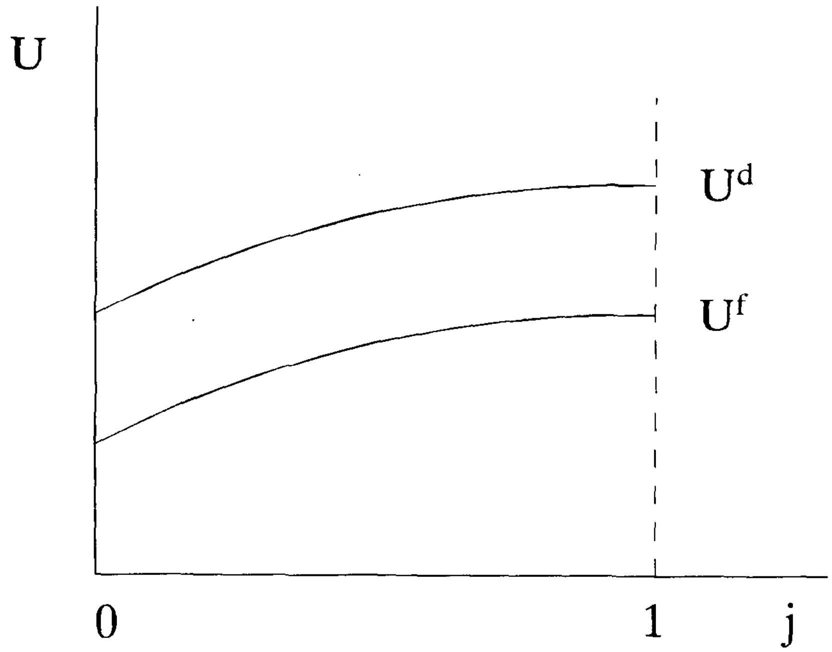


Figure 2. Case of Total Migration

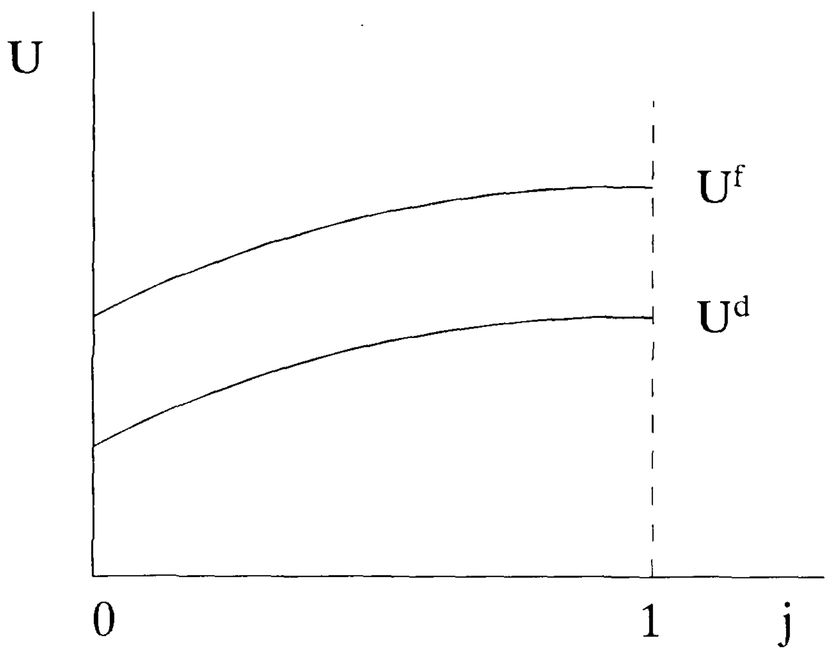
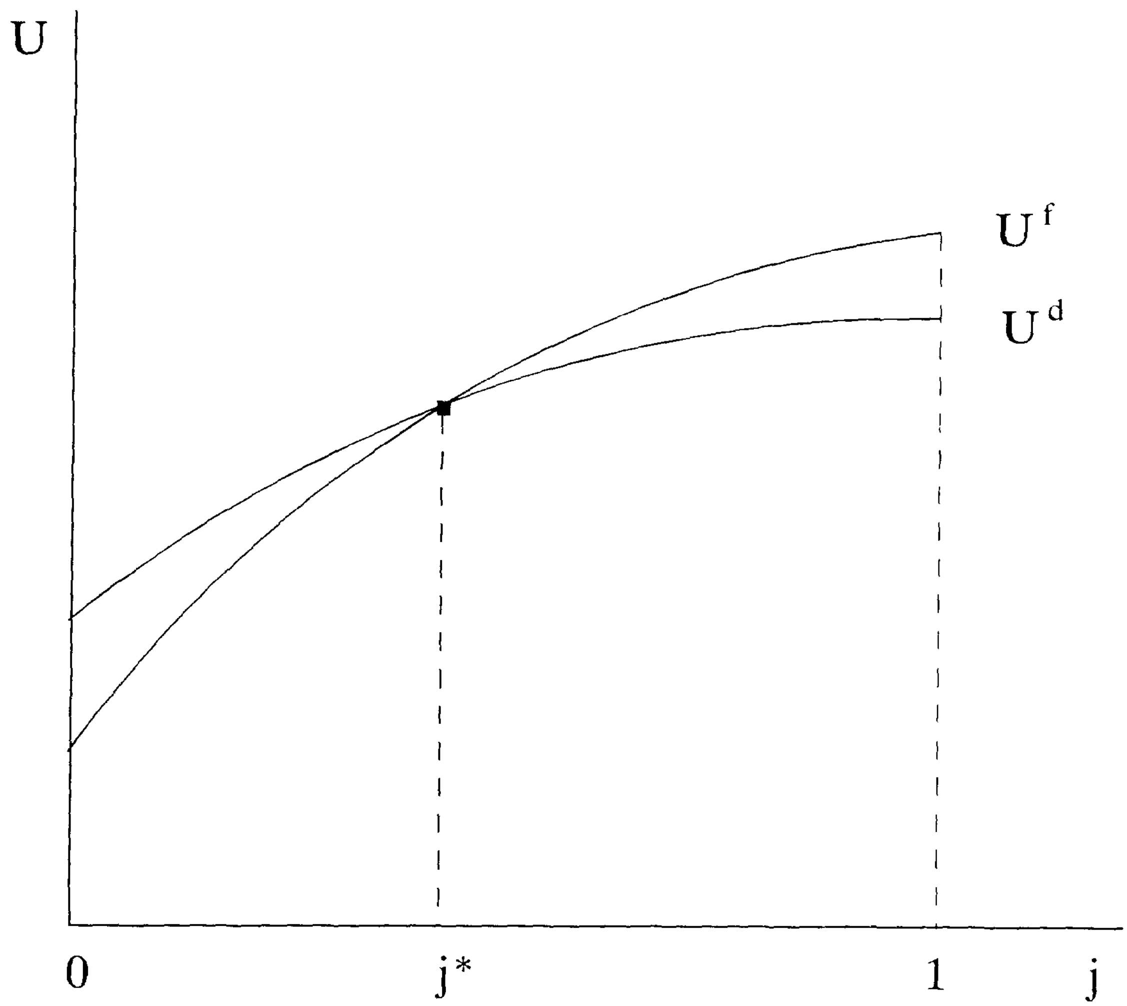


Figure 3. Determination of Human Capital Flight: Case of Partial Migration



δ^* will stand to gain in terms of utility from migration and will therefore move to the foreign country. On the other hand, individuals with abilities below δ^* will not migrate. Hence, $(1-j^*)$ represents the fraction of human capital flight among the total population. Further, this j^*-th agent is important since this agent's human capital efficiency parameter (δ^*) represents the divide between the migrants and non-migrants, and hence decides the average level of human capital that stays in the economy. Further, as we shall see later, the level of average human capital that remains in the economy then determines the rate of growth of the economy.

The individual in the margin, j^*, can be calculated as a closed form. Using the labor market equilibrium condition $w_t = A$ and equation (8), the equilibrium j^* can be calculated to be:

$$j^* = \frac{X}{b\,H} - (m/b-1/2), \tag{20}$$

where

$$X = \frac{[(\gamma/(1-\tau_f)q\lambda A) - (1 - [(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})]}{(1 - [(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})}. \tag{21}$$

Using the above expression on j^*, we can establish the following proposition on the effects of various parameters on human capital flight.
Proposition 2: The equilibrium human capital flight ratio $(1-j^*) \in (0,1)$ decreases with the cost of migration γ and tax rate of foreign country, τ_f, and increases with the assimilation parameter, q, the relative level of foreign technology, λ, subsidy rates, a and c, and average level of educational abilities, m, and domestic tax rate, τ_d. Alternatively,

$$\frac{\partial j^*}{\partial \gamma} >0;\ \frac{\partial j^*}{\partial q} <0;\ \frac{\partial j^*}{\partial \lambda} <0;\ \frac{\partial j^*}{\partial m} <0;\ \frac{\partial j^*}{\partial a} <0;\ \frac{\partial j^*}{\partial c} <0;\ \frac{\partial j^*}{\partial \tau_d} <0;\ \frac{\partial j^*}{\partial \tau_f} >0. \tag{22}$$

Proof: <u>See Appendix</u>

The ability cut-off point therefore varies directly with the relative tax policy of the domestic government as well as technology parameters. As the cost of migration, γ, increases, it increases the ability cut off point thus increasing domestic retention of the more able. An example of an increase in this parameter is the Bhagwati "brain drain" tax which would slow down the rate of human capital flight and retain the more able at home.

The after-tax wage differential between the home and the foreign country also affects where the domestic human capital distribution will be truncated; the higher the tax differential, the lower the point of truncation. Similarly, this point of truncation is reduced with increases in subsidies as well as increases in average levels of education in the home country. An increase in q which implies a reduction in assimilation costs allows for a lower j^* to prevail. This explains, for example, the observation that much of human capital flight from former colonies takes place to their original colonial centers; it is perhaps because of common language and other cultural ties--factors which serve to lower assimilation costs.

Finally, note that in equilibrium, j^* and hence the amount of the brain drain does not depend on h_t, which implies that a fraction of population which migrates to foreign country remains constant over time. As a result, the ratio of population of the country with emigration and immigration remains constant at $(2+j^*)/(2-j^*)$. This is to be expected given our assumption of a constant population. Each period, the older generation is replaced by an exactly equivalent number of the young. Of the generation that is now becoming old, some proportion j^* migrate to the foreign country and $(1-j^*)$ remain behind leaving the ratio of the populations in the two countries unchanged.

IV. Growth Consequences of Human Capital Flight

As we have seen, a certain fraction of the old will migrate from the home country to the foreign country if the difference between wage tax rates of the two countries is large relative to assimilation and other migration costs. We can now examine the effect of brain drain on the rates of growth of the two countries.

Consider first the effect of brain drain on the country of emigration. The average level of human capital of parents' generation ($h^E{}_{t+1}$) in period $t+1$ in the country from where migration has taken place can be written as follows: 1/

$$h^E{}_{t+1} = \frac{\int_0^{j^*} h^j_{t+1}\, dj}{j^*}. \tag{23}$$

The corresponding per capita growth rate ($g^E{}_{t+1}$) of the country can be calculated as follows:

1/ The superscript "E" is used to denote the country of emigration and the "I", the country to which migration takes place.

$$
\begin{aligned}
g^E_{t+1} &= Y^E_{t+1}/Y^E_t - 1 \\
&= \frac{\int_0^{j^*} h^j_{t+1} dj}{\int_0^{j^*} h^j_t dj} - 1 \\
&= \frac{\int_0^{j^*} (1+\delta^j v^j) dj}{j^*} - 1 \\
&= \frac{\beta H}{1+\beta} (bj^*/2 + m - b/2) - \frac{1}{1+\beta}.
\end{aligned} \tag{24}
$$

As can be seen from the above equation, the growth rate of the country of emigration is an increasing function of j^*, that is, a decreasing function of brain drain. The reason is that those who remain in the country are the less able and accumulate less human capital than the people who go abroad. In addition, the growth rate remains constant over time, since j^* stays constant over time. This implies that brain drain generates a permanent reduction in the long-run growth rate of the country with emigration. That is, brain drain has a *growth effect*.

The effect of brain drain on the growth of the economy of the country from which migration has taken place can be calculated to be:

$$
g^E_{t+1}\Big|_{\substack{without\\ migration}} - g^E_{t+1}\Big|_{\substack{with\\ migration}} = \frac{b\beta H}{2(1+\beta)} (1-j^*). \tag{25}
$$

This expression suggests that the magnitude of the reduction in the growth rate is proportional to the fraction of population that has migrated.

This can be summarized as follows:

Proposition 3: Human capital flight generates a permanent reduction of per capita income growth rate in the home country, the magnitude of which is proportional to the fraction of the population that has migrated.

On the other hand, the country of immigration has the average level of human capital of old workers (h^I_{t+1}) in period *t+1* which is calculated to be an average of human capital of natives and immigrants as follows:

$$h^{I}_{t+1} = \frac{\int_0^1 h^{I,j}_{t+1} \; dj + \int_{j^*}^1 h^{E,j}_{t+1} \; dj}{1 + (1-j^*)}. \tag{26}$$

The country's per capita growth rate (g^{I}_{t+1}) will be given by:

$$\begin{aligned} g^{I}_{t+1} &= Y^{I}_{t+1}/Y^{I}_{t} - 1 \\ &= \frac{\int_0^1 h^{I,j}_{t+1} dj + \int_{j^*}^1 h^{E,j}_{t+1} dj}{\int_0^1 h^{I,j}_{t} dj + \int_{j^*}^1 h^{E,j}_{t} dj} - 1 \\ &= \frac{\int_0^1 (1+\delta^j v^j) dj}{1+(1-j^*)} + \frac{\int_{j^*}^1 (1+\delta^j v^j) dj}{1+(1-j^*)} (h^{E}_{t}/h^{I}_{t}) - 1. \end{aligned} \tag{27}$$

The final expression shows that the magnitude of the growth effect in the country of immigration varies over time depending on the evolution of the ratios of the average levels of human capital, which in turn, hinges on the ratio of the growth rates in the two countries. Consider a case where the average level of human capital in the country from which flight takes place far exceeds that of the country to which migration is taking place at a time when migration starts. For the initial periods in this case, immigration will raise the average level of human capital in the receiving country and consequently, make a substantial contribution to the acceleration of the growth rate of that country. However, since the receiving country grows more rapidly than the sending country, (h^{E}_{t}/h^{I}_{t}) will decline. As a result, the positive contribution of human capital flight on the receiving country's growth will be reduced over time.

On the other hand, consider the case of immigrants coming from a country with very low level of human capital. In this case, immigrants can decelerate the growth rate of the country with immigration. Even though immigrants have higher average education ability than the natives of their home country, their contribution to their country of choice will be small because they bring with them relatively poorer human capital than that which is already available in the country of migration. Consequently, in this case, their impact on the average level of human capital and, therefore on the growth rate of the country to which they have migrated can be negative. However, as long as the country of immigration grows less rapidly than that of emigration, (h^{E}_{t}/h^{I}_{t}) will increase and hence the receiving country's growth rate will increase.

We can summarize the above discussion in the following proposition:

Proposition 4: The extent to which human capital flight increases the growth in the receiving country varies directly with the evolution of the ratio of the average level of human capital in the sending and the receiving countries.

Finally, we illustrate that human capital flight can lead to differences in growth rates as well as in levels of per capita incomes in the long run across countries. The magnitude of the difference between the growth rates of the two countries induced by brain drain can be obtained by subtracting (24) from (27) and is given by:

$$g_{t+1}^{I} - g_{t+1}^{E} = \frac{\int_0^1 (1+\delta^j v^j)\,dj}{1+(1-j^*)} + \frac{\int_{j^*}^1 (1+\delta^j v^j)\,dj}{1+(1-j^*)} (h_t^E/h_t^I) - \frac{\int_0^{j^*} (1+\delta^j v^j)\,dj}{j^*} . \tag{28}$$

This tells us that the magnitude of the difference in the growth rate at time t depends on the relative human capital ratio of the two country $(h^E{}_t/h^I{}_t)$ as well as the parameters affecting j^* which include average and variance of education abilities, subjective discount rate, tax rates, education subsidies, and assimilation costs. 1/

The difference in the steady state growth rate of the two countries does not depend on $(h^E{}_t/h^I{}_t)$, but the parameters affecting the human capital flight. Rewriting (28) as follows:

$$g_{t+1}^{I} - g_{t+1}^{E} = g^{I,N} + g^{I,F} - g^{E} , \tag{29}$$

we first consider the case where 2/

1/ See proposition 2 above.
2/ $g^{I,N}$ refers to the component of the growth of the receiving country which is due to the residents of the country and $g^{I,F}$ refers to the component which is due to the migrants. As Figure 2 illustrates and as discussed above, the first part of these components remains fixed, whereas the latter is varying, over time in accordance with the relative human capital levels of the two countries.

$$g^{I,N} < g^{E}, \tag{30}$$

i.e., the first factor of (28) is less than the third. In this case, if we assume that the country with immigration grows more rapidly at the initial period t_0, the relative human capital (h_t^E/h_t^I) and the growth rate of the country is decreasing as case (i) in Figure 4. If we assume the receiving country grows less rapidly at t_0, (h_t^E/h_t^I) and the growth rate are increasing as in case (ii) in Figure 4. In both cases, however, once (h_t^E/h_t^I) reaches to a constant level which equilibrates (28), the ratio will remain the same at the level. At this steady state level, although the growth rate of the country to which immigration has taken place will be equal to that of the country from which immigration has taken place, the income level of the country of immigration is different from that of the country of emigration. Consequently, in this case, brain drain induced by different taxation generates a *level* difference across countries in the steady state.

Consider the opposite case where these parameters satisfies the following inequality:

$$g^{I,N} > g^{E}. \tag{31}$$

In this case, as illustrated in case (iii) in Figure 4, human capital flight generates a difference in income levels as well as growth rates across countries in the long run. The above inequality implies that the country of immigration grows more rapidly, and hence the relative human capital (h_t^E/h_t^I) and the growth rate are decreasing over time. However, the growth rate converges to some steady state level $(g^{I,N})$. In the steady state, therefore, the steady state growth rate of the country of migration remains higher than that of the country of emigration (g^E).

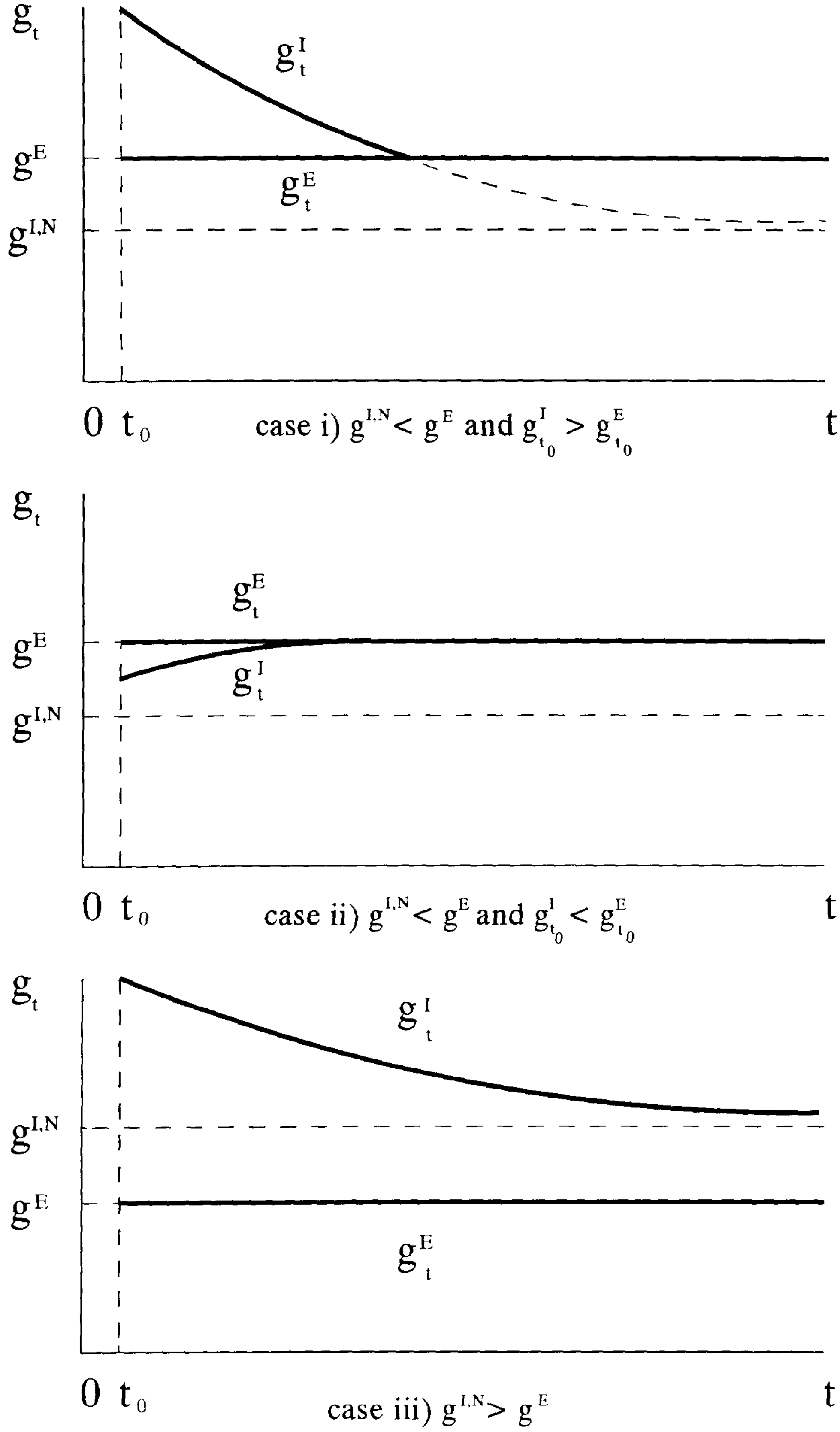
The above discussion can be summarized in the following proposition:

Proposition 5: Human capital flight can generate a difference in growth as well as level of incomes across countries.

V. Growth Effects of Taxes and Subsidies

Government policy which in this model is restricted to a tax-financed subsidy on education, now have an important impact on output growth through brain drain. In particular, we have already seen that increased tax differentials that serve to make foreign wages more attractive will result in an increased human capital flight. More importantly, in a heterogeneous agent environment, as wage differentials increase, the better educated and skilled individuals migrate resulting in a loss of output and growth because human capital here is an engine of growth.

Figure 4. Time Path of Growth Rates



In view of this importance of human capital in the production process and given the heterogeneity of individuals, alternate tax and subsidy policies could be considered. We first put forth the following proposition on the growth effect of tax-financed increase in education subsidies.

Proposition 6: In a closed economy, a tax-financed increase in education subsidy that preserves the fiscal balance, will induce a positive growth effect, while in an open economy (where labor is mobile) such a policy can have a negative impact on growth.

Proof: See Appendix.

This proposition tells us that in the absence of brain drain, increases in education subsidies always raise the rate of return from education and hence induce more human capital accumulation and, accordingly raise growth. Further, increases in wage tax rate also has a non-negative effect on growth. In the presence of education subsidies for young age, which implies less resources in the old period, an increase in wage tax rate makes resources available for old age relatively scarce. Hence, utility-maximizing agents seek to smooth consumptions by increasing their transfer through education, which increase the growth rate. 1/ Thus, in the absence of human capital flight, an increase in government spending to subsidize education financed by wage tax will increase the growth rate keeping the government budget balanced.

In the presence of human capital flight, however, such expansionary government policy can have totally different implications for economic growth. The reason is that, as equation (24) indicated, human capital accumulation and growth rate are now affected not only by H, but also by j^*, i.e., brain drain. An increase in subsidy rates will increase H, but decrease j^*, i.e., increase human capital flight (see proposition 2). Hence such a presence of human capital flight will reduce the magnitude of the growth effect of subsidies.

Using equation (20), we can rewrite equation (24) as

$$g^E_{t+1} = \frac{X\,\beta}{2(1+\beta)} + \frac{(m-b/2)\,H\,\beta}{2(1+\beta)} - \frac{1}{(1+\beta)}. \qquad (32)$$

1/ In endogenous growth models where human capital accumulation depends on time spent on education, the sign of $(dH/d\tau_d)$ depends on the existence of subsidies. In case of no subsidies, the wage tax rate does not affect the growth rate since it affects the current and future after-tax wage equivalently (see Lucas(1990)).

This expression shows that, in the case where the education efficiency of the least able who is indexed by (m-b/2) is close to zero, education subsidies will have little effect on the growth rate because the human capital flight effect of subsidies will be almost equal to the human capital accumulation effect through H.

On the other hand, wage tax rates will have a substantial negative effect on the growth rate since the human capital flight effects dominate the human capital accumulation effects when (m-b/2) is close to zero. Hence increases in government tax-finance subsidies will have negative effects on the growth rate.

The optimal choice between education and lump-sum subsidy for a given amount of government revenues can also be analyzed. In particular, we focus on the different effect of two subsidy policies: (a) a subsidy that increases with the level of education, and (b) a subsidy that declines with the level of individual education.

Proposition 7: In both a closed economy and an open economy (where labor is mobile), a proportional subsidy to education leads to higher growth than a lump-sum subsidy for the same revenue effect.

Proof: See Appendix.

This result favors subsidies to education which directly affect the incentives for human capital accumulation rather than lump-sum subsidies.

Finally, we can consider the choice between a subsidy the rate of which is uniform up to an ability level and then takes different value beyond that level such that higher levels of education get a less subsidy than lower levels. We expressed education subsidy rate as two different types as

$$a = a_1 \qquad for\ j < j^0, \tag{33}$$

$$a = a_2 \qquad for\ j > j^0, \tag{34}$$

where a_1 and a_2 are two different uniform rates of subsidies and j^0 is the agent above whom a different subsidy rate is applied.

Then the optimal education subsidy for a given amount of government revenues can also be calculated.

Proposition 8: The growth-maximizing combination of subsidies given government budget constraint would be a proportionate subsidy up to ability level δ^* and zero subsidy beyond the level.

Proof: We first show that a subsidy to higher levels of education which induces brain drain is inferior to a uniform subsidy as follows. It can be easily shown that the growth effect of uniform tax rate a_1, (dg/da_1), is positive, and revenue effects of both type of subsidies, (dR/da_1) and (dR/da_1), are also positive. However, as long as j^0 is equal to or greater than the truncation point for brain drain, j^*, the growth effect of subsidies for the people above j^*, (dg/da_2), is zero. In addition, proposition 7 shows that a proportional subsidy is more effective in growth-enhancement than lump-sum subsidies. Hence proposition 8 follows. ‖

This proposition suggests that a replacement of subsidies on higher levels of education by those on lower levels will increase the growth rate keeping the spending constant. The reason is as follows. Increases in subsidies on higher levels will increase the education of the more able. However, the fraction of the population which benefit from the education subsidies will migrate, and hence they will not make any contribution to the income growth of the country even though they impose a burden on the government budget. Hence this result favors education subsidies which increases with education up to a certain point against concentration of subsidies on higher level of education.

VI. Some Extensions

Although the model that has been developed in this paper has been used to study the incidence of the brain drain, that is, migration where the more able move out, while the less able stay at home, it can easily be extended to studying growth implications of a variety of patterns of migration. Specifically, by altering the mix of tax and subsidy policies, technology, migration and assimilation costs, and preference structures, we can study situations other than where only the most able or the most productive migrate. Depending on the configuration of these parameters, migration can also take place simultaneously from different segments of the ability distribution.

For example, a highly progressive tax system in the foreign country and/or a highly regressive tax system in home country could induce migration from the lower segment of the ability distribution. This case could only arise in the extremely unlikely case of a policy mix that essentially induces a higher after-tax wage (lower tax) at the lower ability levels and lower after-tax wage (higher tax) at the higher ability levels in the immigrating country relative to the country to which migration has taken place (see Figure 5). In this case, migration could have positive growth effects contrary to the results presented here.

There is no reason to assume that the migration would be such that it truncates the ability distribution only once. It could be such that those above or below a certain ability level move. The inter-relationship of the tax and subsidy policies, migration costs and assimilation parameters could affect the utilities of the citizens of the two countries in non-linear fashions. Figure 6 presents one such possibility, where migration is taking place from both the upper and lower tail of the distribution. In this case there are two fixed points--j^* and j^{**}. The incentives are such that those below j^* and above j^{**} migrate, while those between j^* and j^{**} stay at home. 1/

Some alterations of the assumption of the inter-generational transmission of human capital or the constant returns to production will not alter the direction of the results but only their magnitude. Instead of assuming that the inter-generational externality is proportional to the average level of skills of parents' generation i.e., that all the parents have a positive effect on the human capital of offsprings' generation, we can assume that the inter-generational externality depends only on some segment of the upper tail of the ability level of the parent generation. In this case the growth effect of brain drain will be magnified without changing the qualitative results. Similarly, the assumption of a constant returns to scale to human capital is not critical to draw the conclusion of the long-run growth effect of the brain drain. In the case of diminishing returns to scale, apart from the magnitude of the growth rate of GNP being reduced to a level consistent with the returns to scale assumption, other results will remain broadly similar. 2/

Allowing remittances from migrant workers would be an interesting extension in view of the importance of such flows to a number of developing countries. Remittances could be motivated by including in the migrant utility function altruism towards the consumption of the family left in the home country. In this case, the incomes of the non-migrants could be increased by remittances even to levels beyond the levels of a closed economy if migrants had strongly altruistic feelings. 3/ Nevertheless, migration would continue to affect the growth rate in the same manner as we have analyzed.

VII. Conclusion

Despite the reinforcement of the role of human capital in the generation of growth by recent research, the international movement of such capital has not been studied even though there has been interest in the mobility of physical capital. Although the issue of the "brain drain" did

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1/ This phenomenon is probably observed quite frequently in most developing countries since migrant workers tend to be either highly educated such as doctors, researchers, engineers etc. or low skilled manual laborers like cab drivers. This phenomenon is also quite frequently induced by policy which allows only for migration from the two ends of the ability distribution (e.g., the U.S.).

2/ As long as human capital grows at a constant rate, so does output.

3/ In recent years, remittances from migrant workers, have been an important source of inflows to many developing countries.

Figure 5. Migration of Less Skilled

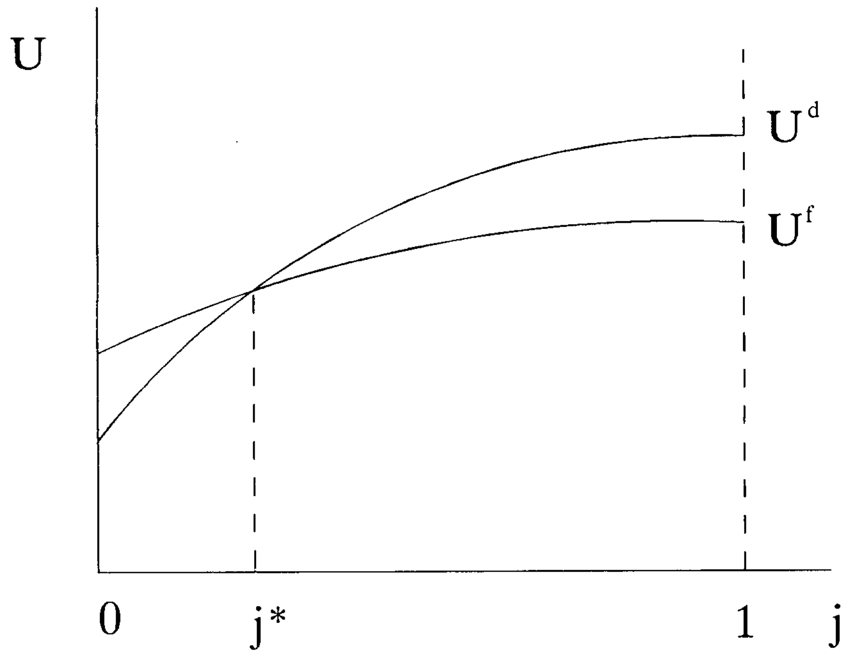
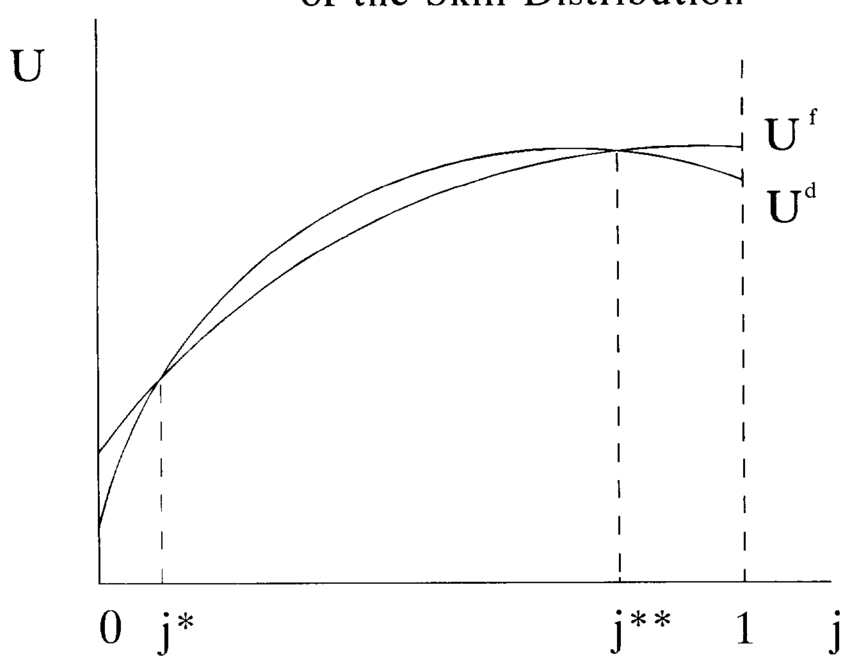


Figure 6. Migration From Both Ends of the Skill Distribution



receive a fair amount of attention in the seventies, and remains of interest in developing countries, the consequences of this problem of economic growth have not been carefully analyzed. 1/ Just as capital flight is hypothesized to result from differing returns between the domestic and the international economy, this paper motivates the flight of human capital or the migration of the more skilled or the more able as a result of higher rates of return for work in the foreign country than at home. 2/ The differences in rates of return may arise out of differing government policies or technology and persist even if there is a preference for staying at home. This paper has examined the impact of migration of human capital on the growth and levels of incomes in the context of an endogenous growth model. We have also identified the influence of tax policy and other variables on migration and economic growth. We have shown that this migration may lead to not only sustained differences in income levels but also in growth rates between countries.

Using a two-country endogenous growth model with heterogeneous agents, we have studied the impact on growth and incomes of migration of human capital that could arise because of wage differentials. Our model shows that if the economy is closed, i.e., there is no labor mobility, wage/tax/subsidy policy at home is independent of that in the foreign country. In a world of perfect labor mobility where there are no costs of migration nor any assimilation costs, small wage or tax differentials will result in the entire population of the country with the lower wage (higher tax rate) migrating to the one with the higher wage (lower tax rate).

We have shown that, in more likely intermediate case, wage differentials as well as migration and assimilation costs, will result in a truncation of the distribution of talent in the country of emigration. Individuals with abilities above this truncation point will migrate, and those below will stay at home. The after-tax wage differential between the home and the foreign country determines where the domestic human capital distribution will be truncated; the higher the tax differential, the lower the point of truncation. This point of truncation is reduced with decreases in migration and assimilation costs as well as increases in average levels of education in the home country.

Because brain drain reduces the growth rate of the effective human capital that remains in the economy and hence generates a permanent reduction of per capita growth in the home country. It also can induce an increase in the growth rate of the country to which migration has taken place although the effect can vary over time depending on the evolution of the ratio of average human capital of the two countries. We have also shown that migration of human capital can lead to differences in the growth rates as well as in levels of per capita incomes in the long run across countries. The magnitude of the adverse impact of the brain drain depends on what the

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1/ See Bhagwati and Partington (1976).

2/ See Khan and Haque (1985) for an approach to modelling capital flight.

contribution of the quality of differing levels of human capital is in the production process. Unfortunately, this is an area on which little theoretical work has been done and is extremely difficult to develop any empirical evidence on.

Finally, we have also derived implications for policies to foster human capital accumulation using subsidies on education. In a closed economy, a tax-financed increase in education subsidy that preserves the fiscal balance, will induce a positive growth effect while in an open economy (where labor is mobile) such a policy can have a negative impact on growth. Given the impact of human capital on output and growth, a policy that increases the subsidy to higher levels of education might at first glance be seen to serve to increase growth in the economy. However, since migration takes place beyond a particular education level, the growth-promoting policy should take this information into account. Consequently, in the presence of brain drain, it would be growth-maximizing to allow the subsidy to increase with the education effort up to this level of education, and then be set at zero.

The analysis presented above has important implications for the economic policy in developing countries. Human capital flight is an additional dimension that should be taken into account in the determination of monetary and fiscal policies in view of the adverse growth consequences of human capital flight, and of how policies such as taxes, subsidy and any direct wage restraints that induce differentials in rates of return on education can induce such flight. These policies are often key elements in stabilization and structural adjustment programs. Demand management is often an important element of such programs and is frequently achieved by a combination of increased taxes and wage restraints. To the extent that ability is an important determinant of growth, the design of such programs should be concerned with the consequences of such policies for migration.

Proof of Proposition 2

From the expression on the equilibrium j^* in equation (20), the derivatives of the truncation point with respect to individual parameters can be obtained. To determine the sign of the derivatives, the following facts are used: for positive δ, X should be positive, which implies that $(1-\tau_f)q\lambda$ is greater than $(1-\tau_d)$. The sign of the derivatives are as follows:

$$\frac{dj^*}{d\gamma} = \frac{X}{\gamma\, b\, H} > 0 \tag{35}$$

$$\frac{dj^*}{dq} = -\frac{\lambda[\gamma\,(1+(\beta/(1+\beta))\,(1/([(1-\tau_f)q\lambda/(1-\tau_d)]\,-1))]}{b\,H\,[(1-\tau_f)q^2\lambda^2A\,(1-[(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})]} < 0 \tag{36}$$

$$\frac{dj^*}{d\lambda} = -\frac{q[\gamma\,(1+(\beta/(1+\beta))\,(1/([(1-\tau_f)q\lambda/(1-\tau_d)]\,-1))]}{b\,H\,[(1-\tau_f)q^2\lambda^2A\,(1-[(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})]} < 0 \tag{37}$$

$$\frac{dj^*}{da} = -\frac{X}{b\,((1-\tau_d)A+c)} < 0 \tag{38}$$

$$\frac{dj^*}{dc} = -\frac{X\,((1-\tau_d)A-a)}{b\,((1-\tau_d)A+c)^2} < 0 \tag{39}$$

$$\frac{dj^*}{dm} = -\frac{1}{b} < 0 \tag{40}$$

$$\frac{dj^*}{d\tau_d} = - \frac{\gamma A(\beta/(1+\beta))[(1-\tau_f)q\lambda/(1-\tau_d)]^{1/(1+\beta)}}{b\ H\ [(1-\tau_f)q\lambda A\ (1 - [(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})]^2} - \frac{X\ A(a+c)}{b\ ((1-\tau_d)A+c)^2} < 0 \tag{41}$$

$$\frac{dj^*}{d\tau_f} = \frac{\gamma\ [1+ (\beta/(1+\beta))[1/((1-\tau_f)q\lambda/(1-\tau_d)-1)]]}{b\ H\ q\lambda A\ (1-\tau_f)^2\ (1 - [(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})} > 0 \tag{42}$$

Proof of Proposition 6

In the absence of labor mobility, $j^* = 1$. Using the expressions for growth rate derived above, the growth rate (g^E_{t+1}) of the country with emigration can be easily calculated as follows:

$$g^E_{t+1} = \frac{\beta\ m\ H}{1+\beta} - \frac{1}{1+\beta}. \tag{43}$$

where $H = ((1-\tau_d)A + c)/(1-\tau_d)A - a)$.

The derivatives of the growth rate with respect to policy variables are: $\partial g^E_{t+1}/\partial c = (\beta m/(1+\beta))(\partial H/\partial c)$, $\partial g^E_{t+1}/\partial a = (\beta m/(1+\beta))(\partial H/\partial a)$ and $\partial g^E_{t+1}/\partial \tau_d = (\beta m/(1+\beta))(\partial H/\partial \tau_d)$.

It can be shown that $\partial H/\partial c > 0$, $\partial H/\partial a > 0$ and $\partial H/\partial \tau_d > 0$. Then it follows that the rate of growth is an increasing function of tax-financed education subsidies.

In the case of positive brain drain, $j^* < 1$. The corresponding growth rate (g^E_{t+1}) of the country is given as follows:

$$g^E_{t+1} = \frac{\beta H}{1+\beta}\ (bj^*/2 + m - b/2) - \frac{1}{1+\beta}. \tag{44}$$

Using the expression for j^* in equation (20), the growth rate can be written as:

$$g_{t+1}^{E} = \frac{X\beta}{2(1+\beta)} + \frac{(m-b/2)\,H\,\beta}{2(1+\beta)} - \frac{1}{(1+\beta)}, \tag{45}$$

where

$$X = \frac{[(\gamma/(1-\tau_f)q\lambda A) - (1 - [(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})]}{(1 - [(1-\tau_d)/(1-\tau_f)q\lambda]^{\beta/(1+\beta)})}, \tag{46}$$

Now the derivatives of the growth rate with respect to policy variables can be calculated as: $\partial g^{E}{}_{t+1}/\partial c = (\beta/2(1+\beta))(m-b/2)(\partial H/\partial c)$, $\partial g^{E}{}_{t+1}/\partial a = (\beta/2(1+\beta))(m-b/2)(\partial H/\partial a)$, and $\partial g^{E}{}_{t+1}/\partial \tau_d = (\beta/2(1+\beta))\partial X/\partial \tau_d + (\beta/2(1+\beta))(m-b/2)\partial H/\partial \tau_d$.

It can be easily shown that as (m-b/2) goes to zero, $\partial H/\partial c$, $\partial H/\partial a$ and $\partial H/\partial \tau^d$ goes to zero, and that $\partial X/\partial \tau^d < 0$. Then it follows that the rate of growth is a decreasing function of tax-financed education subsidies. ‖

Proof of Proposition 7

Without labor mobility, education subsidies affect the growth rate only through H. The relative effect of the lump sum and the proportional subsidy parameters, c and a on growth can be calculated as:

$$\frac{(dg/da)}{(dg/dc)} = \frac{(dH/da)\ (\beta m/(1+\beta))}{(dH/dc)\ (\beta m/(1+\beta))} = H, \tag{47}$$

which is greater than one.

On the other hand, the relative effects of a and c on revenues ($R = \int a v^j h_t \, dj + c h_t$) are as follows:

$$\frac{(dR/da)}{(dR/dc)} = \frac{\int_0^1 v^j \, dj + a\int_0^1 (\beta/(1+\beta))(dH/da)dj}{1 + a\int_0^1 (\beta/(1+\beta))(dH/dc)dj} \tag{48}$$

which can be shown less than H.

This implies that one unit of proportional subsidy rate, a, has a bigger growth effect for the same revenue effect. Hence a replacement of c type by a type subsidy will increase the growth rate keeping the spending constant.

The presence of human capital flight does not change this result. With brain drain, the relative growth effects of subsidy parameters are as follows:

$$\frac{(dg/da)}{(dg/dc)} = \frac{(dH/da)\ (m/2 - b/4)(\beta/(1+\beta))}{(dH/dc)\ (m/2 - b/4)(\beta/(1+\beta)} = H, \tag{49}$$

In the presence of brain drain the magnitudes of the growth effect of both type of subsidies are smaller. However, the ratio of the two remain the same as the case of immobility.

On the other hand, the relative effects of a and c on revenues are as follows:

$$\frac{(dR/da)}{(dR/dc)} = \frac{\int_0^{j^*} v^j\, dj + a\int_0^{j^*} (\beta/(1+\beta))(dH/da)dj + (dj^*/da)(dR/dj^*)}{j^* + a\int_0^{j^*}(\beta/(1+\beta))(dH/dc)dj + (dj^*/dc)(dR/dj^*)} \tag{50}$$

which can be shown to be less than H. ‖

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